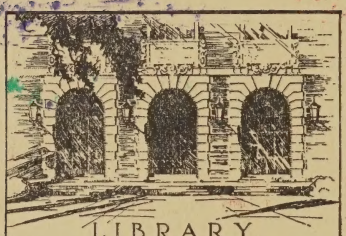

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*ENGINEER BUREAU, UNITED STATES ARMY*

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WOLSEY:

"Might is not all.
Shrewd thinking now wins further than stout blows,
The old arms rust, but from the new forged steel
Come flashings bright with thought. I pray your Grace
Forget that here are colleges and clerks;
Only remember here be men who think,
And even as the brain is master of the hand,
The master of the Nation's task is here.
Here let us build, but not with stones alone;
Let's build with courage, faith, and enterprise,
With daring, and a challenge to the unknown,
And most with honesty. Let's build a house
Wherein by subtle spirit—alchemy
Men may transform the wise high thoughts of old
To new and golden deeds. Then shall we build
As I have dreamed we built"——

*Oxford Historical Pageant, 1907.*

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# LIGHT AND POWER SWITCHBOARDS*

BY

CARYL D. HASKINS
*Manager Lighting Department, General Electric Company*

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The switchboard of an electrical generating station has, as its primary function, the same motive as the switchyard of a railway system.

On to each main track or tracks, known technically as busses or omnibus conducting circuits, are delivered the units of electrical energy which are to be distributed through the system of wiring for lights and motors which are tributary to that particular generating system.

From these busses or this series of busses, for there may be many under some conditions, the feeders or branch lines emanate, radiating in various directions to feed the different branches of the system, sometimes for similar and sometimes for dissimilar classes of work.

In the earliest days of electrical distribution the function of the switchboard, practically speaking, began and ceased within the scope of this brief description. Physically, it was a rack or support holding the main conductors to which the dynamos delivered their energy, and it was equipped with switches for connecting and disconnecting various branch circuits to these main conductors, as the requirements of the system demanded.

These very early structures were little more than wooden posts, connected by a rack work of cross beams holding the copper conductors.

Such structures were, we may say, of the period of 1884. They consisted of mechanical supports of wood, holding conductors of copper suitably arranged, and switches for closing or for opening the circuits. In these early days the switches were seldom double-

*A lecture delivered to the student class at the Engineer School, U. S. Army, Washington Barracks, D. C., April 21, 1908.



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pole. One conductor was generally solid throughout and the second conductor broken by the switch.

However, it was only a short time before some enterprising engineer discovered that it would be a convenience to place upon this same switch rack, as it was termed, the rheostat in series with the field of the generator, to-day known as the field rheostat, in those days known as the control box, and accordingly we find a clumsy package of resistance wire with many contacts and a moving brush secured solidly to the base of the switch rack as its first additional piece of apparatus.

Speedily thereafter provision was made for measuring the current value in amperes of the electric energy passing over the wires of a given circuit.

Originally these structures were placed in the wiring between the dynamo and the busses, and gave indication of how much current the dynamo was giving forth, but almost immediately it was found desirable and of value to also place such instruments in the circuit of each feeder or main branch, telling how many amperes were being sent out to each division of the system.

Almost, but not quite, simultaneously with the appearance of the ampere meter came the voltmeter. Inasmuch as the arc lamp preceded the incandescent lamp, so the ampere meter preceded the voltmeter. It was scarcely a year, however, before the switch rack found itself equipped with not only an ampere meter, or ammeter, for each generator and for each main branch or feeder, but also with a main voltmeter, measuring the voltage generated by the dynamo, and permitting the station attendant to so regulate his field rheostat or regulator box as to keep that voltage approximately normal.

This was the next to the last step in what may be regarded as the primary development of the modern switchboard. There remained one more step of progress to mark the first complete stage.

Early in the art it was made manifest that from time to time a short circuit must be expected. A short has always consisted of the completion of the circuit through an exceedingly low resistance; this low resistance circuit allowing the passage of a current abnormally high in relation to the conductive capacity of the copper both in the circuit itself and in the generator. Such accidents, peculiarly common in the early days of the development of the art, and due most commonly to the blowing or falling together of two wires

on poles without the station, frequently melted the feed wire, set fire to the switch rack or burned out the generator.

Often these unfortunate circumstances were met by the slipping off of the belt between the engine and the generator, or even by the belt's complete disruption, sometimes by the breakage of mechan-

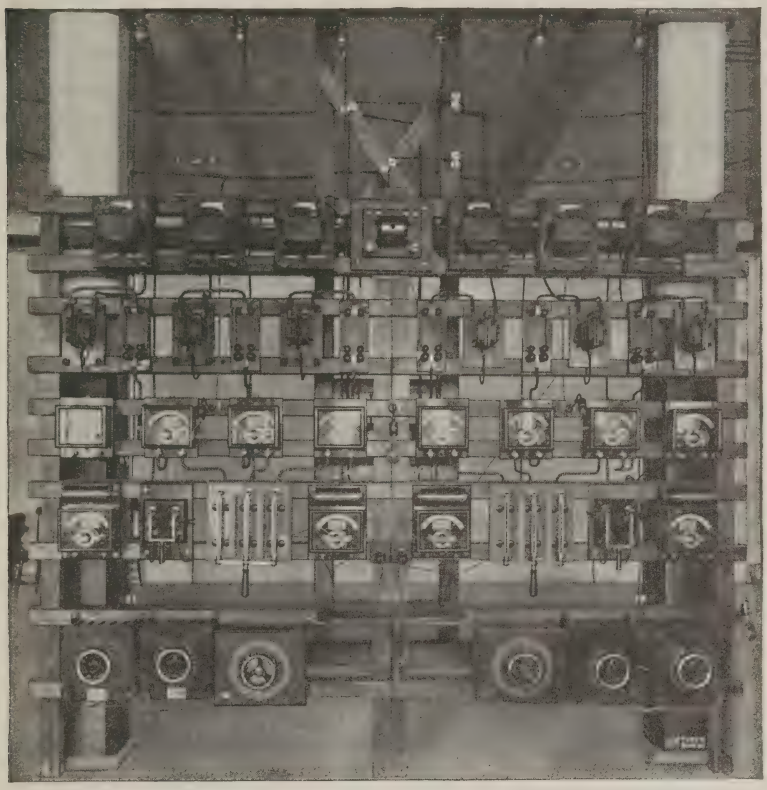

Fig. 1. The switch rack, one of the earliest examples of switchboard design, should be used as a warning.

ical parts of the engine itself, or, perhaps most commonly, by some destructive electrical phenomenon.

The quite obvious remedy, a remedy applied almost immediately, was the safety cut-out or fuse, a weak link deliberately provided in the system which would be destroyed before any other portion of the system could be menaced, and which would protect itself, with its own weakness, the remainder of the circuit.

The earliest forms of safety cut-out or fuse consisted of a considerable length of lead or lead and tin or lead and bismuth wire, through which the normal current passed, but which by reason of its low fusing point would melt away, drip down and render the circuit discontinuous under any abnormal load of current, thus opening the circuit and destroying it before the copper wire, generators, or other apparatus of the system, could be in danger.

At this stage, the first development of the switchboard ceased, its elements were provided and for the first time we find a complete switchboard; the bus, its feeders, the ammeters for measuring the amount of current, the voltmeter for measuring pressure of the sys-

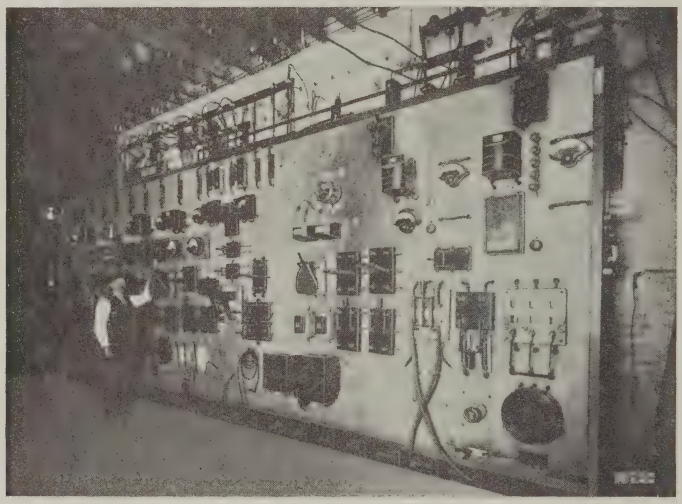

Fig. 2. A brick and mortar switchboard for the control of alternating-current apparatus; without an oil switch, or any safety protection against grounds or short circuits.

tem, the rheostat for controlling the field, and finally, the fuses or safety cut-outs. These combined with a simple wooden framework for their support, and with appropriate switches for completing the continuity or accomplishing the discontinuity of the circuit, gave us the complete switchboard of the early days, as is shown in Fig. 1.

This illustration, however, shows us an early alternating-current switchboard, the earliest switchboard of which I could find a satisfactory photograph, and, inasmuch as this is an alternating-current switchboard, we find upon it certain additional devices, especially applicable to alternating current and not referred to previously as

a portion of the earliest development of the switchboard art. Notably, potential transformers; transformers which serve to reduce the potential impressed upon the system to the same value as that to which it is reduced throughout the system to the lamps, so that, for example, if the ratio of the potential transformers on the switchboard is 10 : 1, a primary voltage upon the outgoing lines of 1,100 volts would show a voltage upon the station voltmeters of 110 volts, or a ratio of 10 : 1, this being the same ratio as that of the

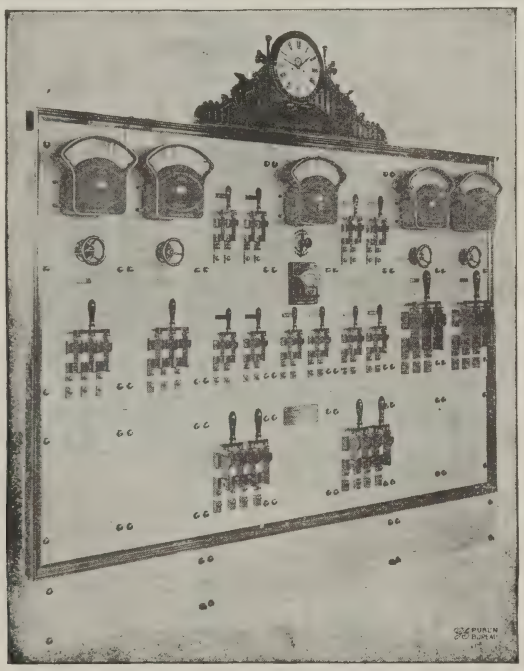

Fig. 3. An ornamental switchboard for direct-current service. Shows ornamental clock and elaborate framework.

line transformers, which reduced at the points of service the current served by the primaries to that applied to the lamps.

Some five hundred central station distributing plants had been established in the United States and were in complete operation before the wooden switch rack came under suspicion, and the art had reached the period of 1890. At about this time there occurred a number of central station fires orginating at the switchboard, and fed by the combustible nature of the supporting structure. The

result was, of course, a prompt stampede towards a thoroughly fireproof construction, and the earliest development in this line was a brick and mortar switchboard (Fig. 2), some few of which are still to be seen in the more primitive central stations throughout the United States.

In essentials they differed from the switch rack of the early days only in being a continuous mass of brick and mortar wall, instead of a wooden skeleton framework (Fig. 1).

From this point the switchboard rapidly drifted into what might

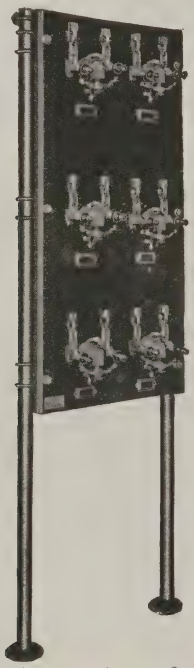

Fig. 4. Small plant generator and feeder switchboard.

be termed its ornamental era. It was found that marble, onyx, and other substances capable of receiving high polish lent themselves well to switchboard construction. The devices that were required for use upon the face of such a switchboard were generally capable of receiving a high and ornamental finish, and electrical apparatus still being of great general interest, the tendency to make the switchboard a display feature of the engine room was yielded to in large measure, and, as a result, we find the highly ornate switchboard almost universally used in the period between 1890 and 1895. Such a switchboard is shown in Fig. 3.

It is a common question for the layman to ask why such ornamental switchboards should be objected to; the answer is that there is no particular objection to them save that they are needlessly costly and bulky compared with the necessary cost and size of a structure to fulfill the same functions.

The clock, an unvarying and costly feature of these boards, was of no real service, and in practice was seldom wound. The Italian marble commonly used in such boards serves no more useful purpose than the black slate from Monson, Maine, at one-half the cost, and has the added disadvantage of showing every stain of oil and every greasy finger mark, whilst the slate improves each time a greasy rag is rubbed across it. The high polish of the instruments and the switches required costly daily upkeep and unceasing labor,

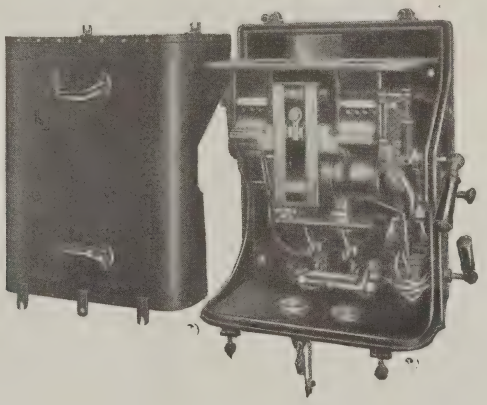

Fig. 5. This illustration shows the latest standard ammunition hoist panel used by the U. S. Navy with the 10-inch and 12-inch hoist.

and contributed nothing to the good operation of the system. The "picture frame" was of no service, and, in short, the expenditure, direct and indirect, was twice that which the necessities of the system demanded.

With the passage into history of the ornamental switchboard, we come to the two final stages:

1st. The stage of maximum utility, and,

2nd. The stage of maximum utility combined with concentration

The utility stage is well typified by the small switchboard shown in Fig. 4.

Here we have a switchboard capable of controlling the output of a generator distributing power over six feeders. Convenience,

economy, and quick operation are the three dominating motives controlling the design of the board. A man standing in front of this board can reach every hand-operated element. The material upon which the devices are mounted is the least costly of all suitable materials—slate, finished with a heavy coating of oil. The framework supporting the panel is of standard gas pipe with a

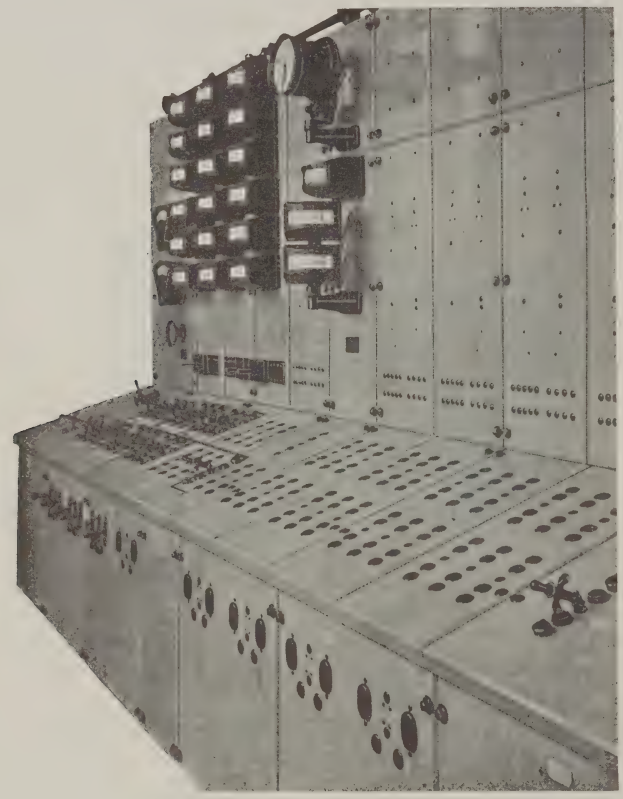

Fig. 6. An alternating-current, remote-control, bench type, switchboard for the Great Northern Power Company, Duluth, Minnesota.

coat or two of paint. Everything speaks of the best use of low cost materials. The generator feeds into the main bus or main conductors through a heavy, but highly simple, copper switch; two instruments, an ammeter showing the total current output from the generator, and a voltmeter showing the voltage upon the system, serve to tell what power is being sent forth into the lines.

The current is distributed out on to the system from the busses through six circuit-breakers—structures to be presently dealt with in detail.

This is essentially a modern switchboard of the simplest type, such an one as may be regarded as satisfactory for the distribution of, say, 100 kilowatts of energy from a single generator throughout an office building or the like, the switchboard before us being a direct-current board.

The switchboard which we have just discussed represents the ultimate in convenience, low cost and general efficiency, but there

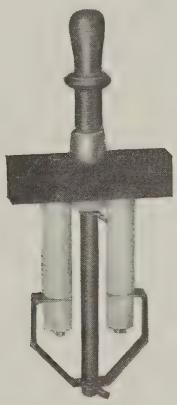

Fig. 7. Illustrates the arc plug switch used on constant current arc systems.

remains still what has become a highly important issue, that of concentration.

In all modern engineering the space factor has become peculiarly important, and the switchboard, naturally a bulky thing, has felt the effect of this perhaps more than most other electrical apparatus.

As an example of extreme concentration in a switchboard, I might cite the present standard naval ammunition hoist panel, shown in Fig. 5.

In this structure, with a space of 11 by 18 by 30 inches, we find a circuit-breaker for controlling the continuity of the circuit, either under manipulation or emergency, a field switch with appropriate discharge resistance for the motor under control, and a low voltage relay, the whole capable of controlling a shunt-wound motor operating an ammunition hoist.

This may be regarded as perhaps the maximum concentration in

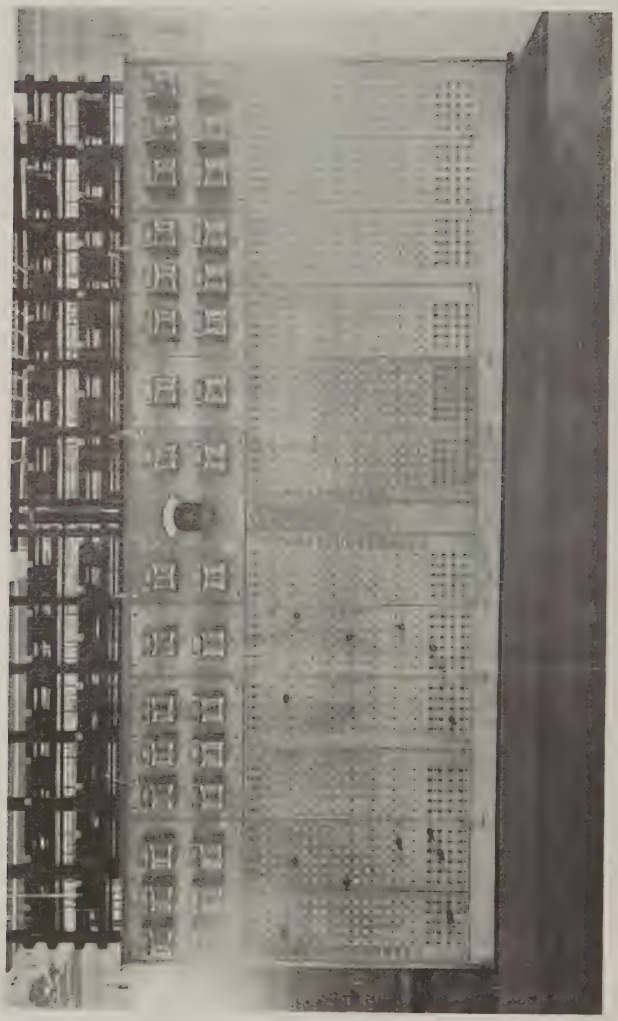

Fig. 8. An arc transfer switchboard for controlling a direct-current series arc lighting system.

switchboards or switchboard panels for the control of what may be termed small amounts of energy.

For the control of large amounts of energy, engineering ingenuity has been further taxed. In a system involving from two to ten large generators of, say, 5,000 kilowatts capacity each, with

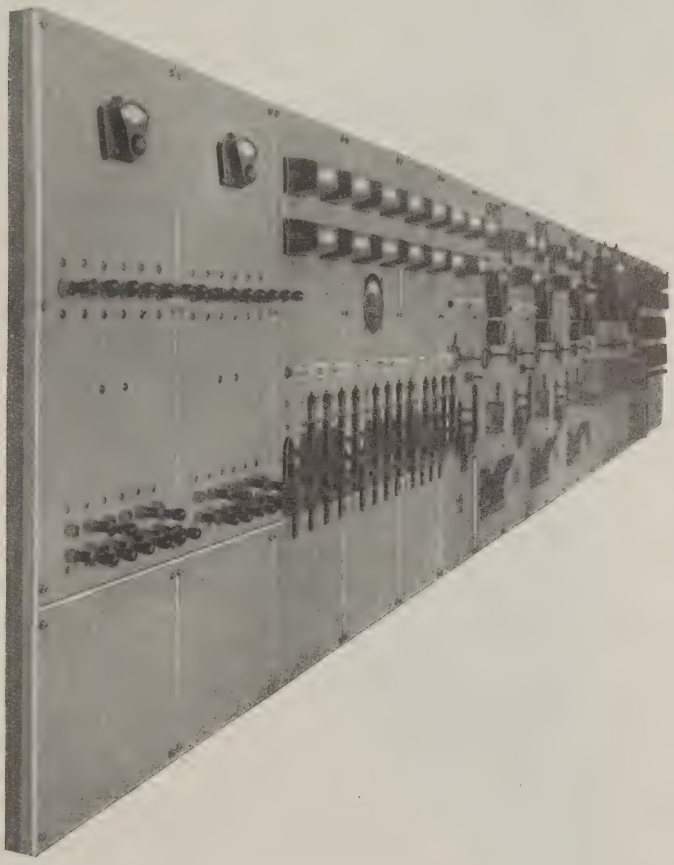

Fig. 9. This illustration shows the alternating-current and direct-current switchboard installed at the U. S. Military Academy at West Point.

several feeders per generator, all connected one to the other in such a manner as to make the system completely flexible, it is obvious that a switchboard laid out upon historic lines would have been hundreds of feet in length, would have cost a vast sum of money, not only for itself but for real estate and roofage, and would have required a very large number of attendants when in operation, and

these conditions being substantially prohibitive, good engineering came to the rescue with a plan of concentration.

In such large undertakings to-day, the switches, the rheostats, indeed all of the moving structures, are packed away compactly in appropriate fireproof cells at a point remote from the board, and are controlled by a series of miniature switches which communicate not with the main switches, but with motors or solenoid devices which automatically open or close the main switches and cut the resist-

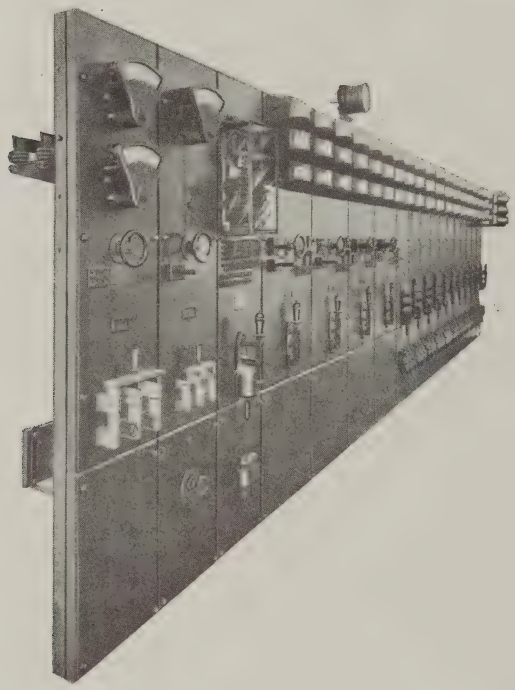

Fig. 10. This illustration shows the front view of a combination alternating-current and direct-current switchboard.

ance in or out of the circuit in accordance with the way the miniature switches upon the operating board are thrown. Such a structure is shown in Fig. 6.

This is a switchboard recently built for the control of the system of the Great Northern Power Co., which from Duluth, Minnesota, distributes power over a wide territory.

It will be noted that the control board is a desk-like structure with many small switches, whose sole function is to complete the

circuit of the small motors which operate the main switches at a remote point.

The small bull's-eyes above and below these switches on the desk-like benchboard are illuminated red or green by positive control

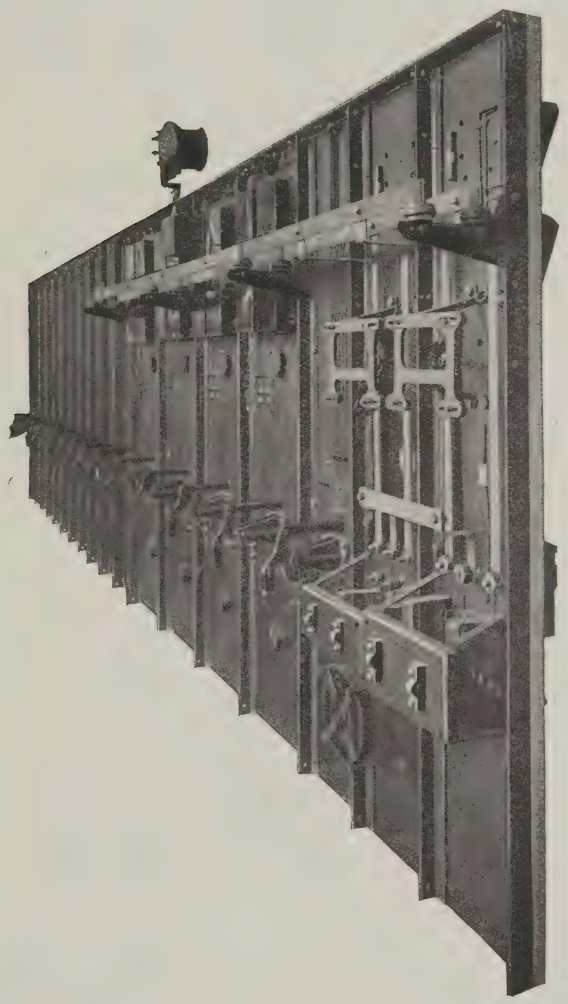

Fig. 11. This illustration shows the back view of the board shown in Fig. 10.

from the main switches, so that the actual position of the main switch is always apparent to the operator.

The handles upon the upright portion of the benchboard control the direction of rotation of a motor geared to a main rheostat, and

an operator with his hand upon one of these rheostat control handles can hold the motor circuit closed in a clockwise or counter-clockwise direction until the appropriate voltmeter which he faces upon the upright panel board before him tells him that the voltage of the circuit which he has under control is at the desired point. This board was chosen particularly because it shows the form of con-

Fig. 12. This illustration shows a standardized panel for an outgoing three-phase feeder circuit.

struction which is generally adopted nowadays for systems which are undergoing rapid extension. Three units of this switchboard are fully equipped, eight are blank and unequipped, but the board is drilled and plugged to receive the requisite appliances when the system grows to demand them, and thus prompt and appropriate extension is accomplished at a minimum of increased cost.

There is still one class of switchboards to which I have not re-

ferred, and that is the switchboard for the control of series arc lighting circuits.

The series arc lighting circuit is characteristically of small current value, as, for example, 6.6 amperes, and differs from the circuits commonly to be dealt with in switchboard problems in that it derives its energy from generating apparatus which is so designed

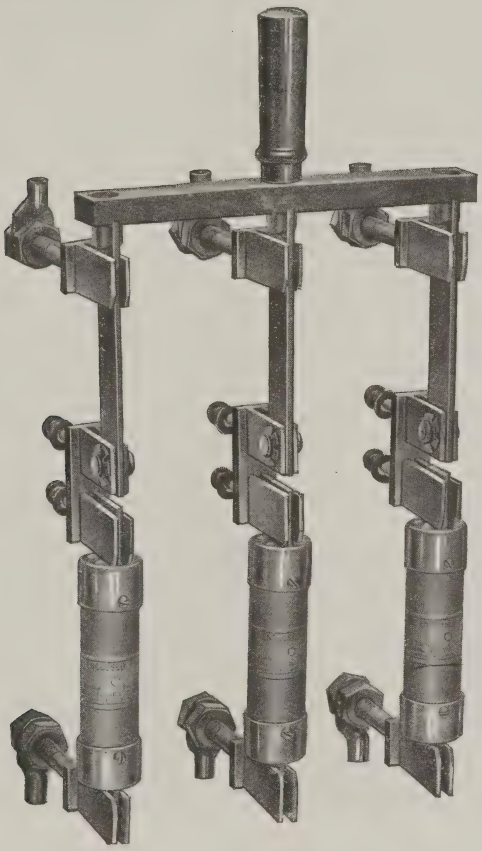

Fig. 13. The lever switch shown in this illustration is known as the D-12 type; it is made in sizes up to 6,000 amperes and in voltages up to 600 volts.

as to deliver an unvarying current value at a voltage adequate to force that current through as many lamps up to its capacity as may be in the system. We have, therefore, to deal with a small amount of current and a large and dangerous voltage

Instead, therefore, of using an ordinary knife-blade switch, the plug or "stab" switch (Fig. 7) is utilized.

A plug switch consists of a cylindrical rod of metal, frequently called a "pencil," set into an insulated handle, and when in disuse is completely detached from the switchboard. The metal portion of this plug is designed to be thrust through an opening in the face of the board, from which it is guided into a snug-fitting hole in a

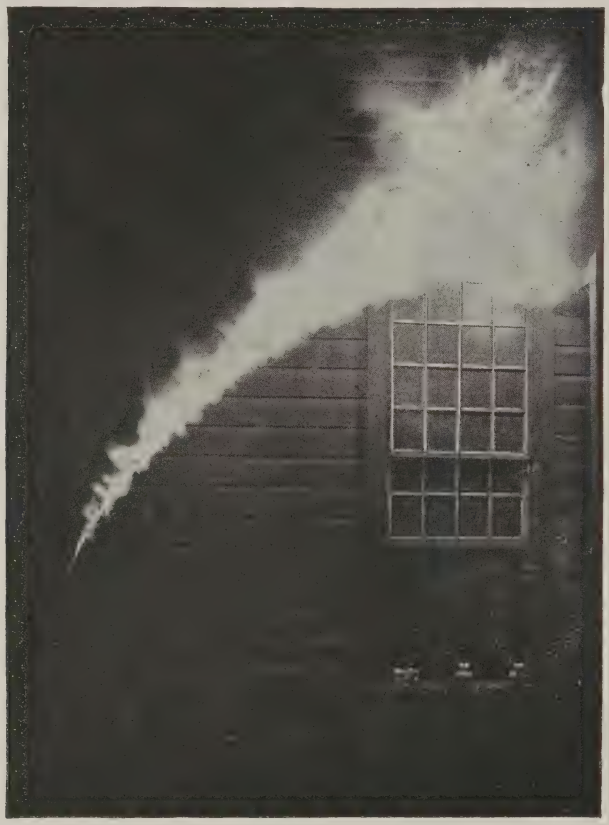

Fig. 14. The illustration shows an improvised automatic break switch in the act of opening a short circuit on one phase of a 2,500-kilowatt, 13,000-volt generator; the distance between the clips of the switch is approximately 11 feet; the arc drawn in opening this amount of energy would be destructive to any station.

metal conductor forming one portion of the conductor, then through a space, commonly within an insulating tube, into a second conductor, into which the plug also fits snugly, thus completing the

continuity of the circuit from one metal portion of the board to another, through a considerable intervening space.

This type of switch is used little, if at all, except in connection with arc circuits where the current is small. Where the current is large, the heat generated at the disruption of the arc would be so considerable as to cause a dangerous volatilization of the metal and a possible short circuit.

A typical but somewhat antique switchboard for the control of arc circuits alone is shown in Fig. 8.

Frequently in a small or moderate sized community a small

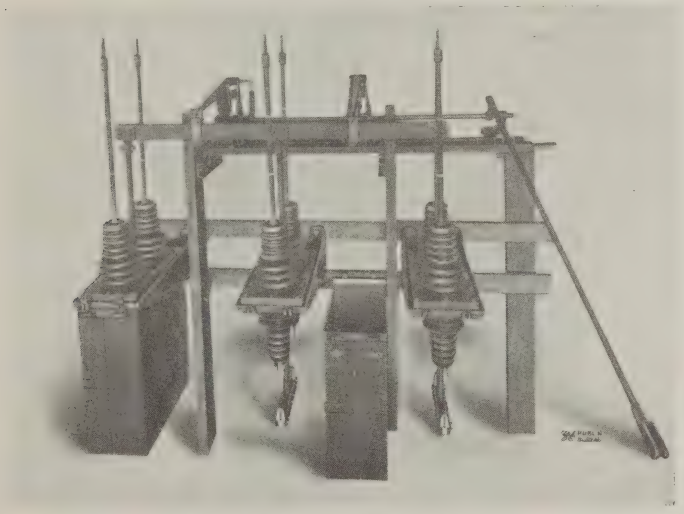

Fig. 15. The illustration shows a 45,000-volt, 100-ampere, oil switch.

generating plant must furnish all kinds of electrical service from a single generator. It must provide constant current, variable voltage service for an arc lighting system for streets and buildings, moderate or high tension alternating-current service for general incandescent lighting and perhaps for induction motors and direct-current service for elevators and, perhaps, even cars. Such a system requires what might be termed a composite switchboard, a switchboard which in reality consists of a number of switchboards brought into close juxtaposition for convenience of operation at the hands of a single attendant.

I have been able to find no better example of such a switchboard

than that shown in Fig. 9, which is the switchboard recently built for the United States Military Academy at West Point.

A thoroughly typical alternating-current switchboard of moderate size is the one illustrated in Fig. 10.

In this switchboard, which is of black slate, the two panels at the extreme left are for the exciters. The next for an induction motor. The fifth, sixth, seventh, and eighth for three-phase generators, and the remainder for feeders. The instrument at the top of the board

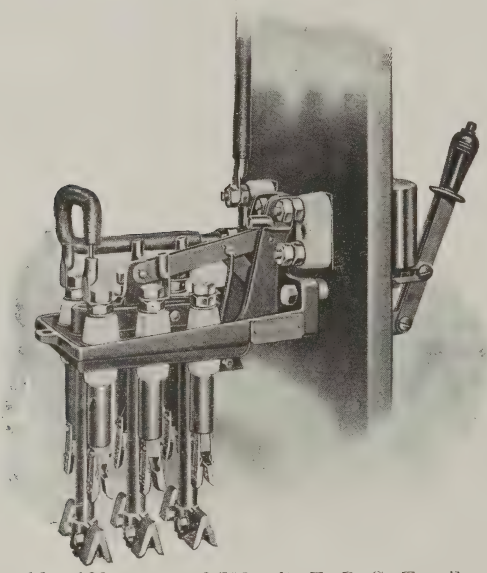

Fig. 16. 100-ampere, 2,500-volt, T. P. S. T., oil switch.

in the center is a synchronism indicator, or synchronoscope, the function of which will be presently described.

Across the lower portion of the board, throughout its alternating-current section, will be noted a series of what are ordinarily termed "relays." These are devices which close a secondary circuit when the main current passing out on the particular line controlled by each particular device exceeds the safety limit for that circuit. The closing of this subsidiary circuit actuates a motor or solenoid on the main switch, causing it to open like a circuit breaker.

Immediately above these relays may be noted the actuating handles of the main switches themselves. The switches proper are located in boards of this type at a point immediately in the rear of the switchboard, and this being an alternating-current system, the

switches are of the oil-break type, presently to be described. Of the generator panels, four are equipped with field rheostat handles, with plugs for connecting to the voltmeter system, and with plugs for connecting to the synchronoscope, whilst the feeder panels are equipped only with plugs for connecting to the voltmeters, so that the voltage on each feeder may be read as required. The systematic manner in which the circuits of a switchboard of this class are ar-

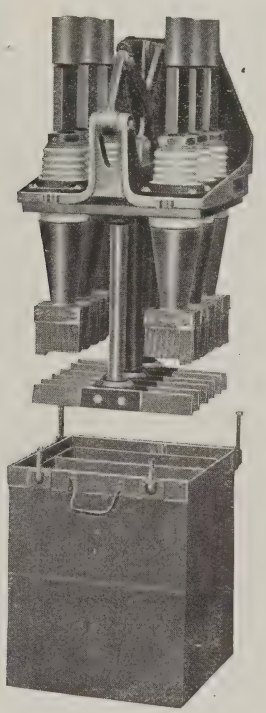

Fig. 17. 1,000-ampere, 2,500-volt, T. P. S. T., oil switch.

ranged is well shown in Fig. 11, which illustrates the back of the board we have just been discussing. In this case the alternating-current wiring has not yet been mounted. The exciter busses are shown at the top right-hand end of the picture. The skeleton mountings for the field rheostats of the generators, the four sprocket wheels which carry the bicycle chain, later to be installed, operating the rheostats, and in a long line from the center to the left of the picture, the bell-crank structures which complete the connection from the handles on the front of the board to the operating switches of the alternating-current system. In these days of standardized

engineering, such boards as this are made up of standardized units, which are capable of combination one with the other in such a manner as to make a few dozen units into hundreds of flexible combinations suited to almost any service. Such a unit is shown in Fig. 12, which is a single feeder panel for a standard alternating-current system. This unit is itself divisible, and made up of separate units. The upper section consists of three ammeters, one for each leg of

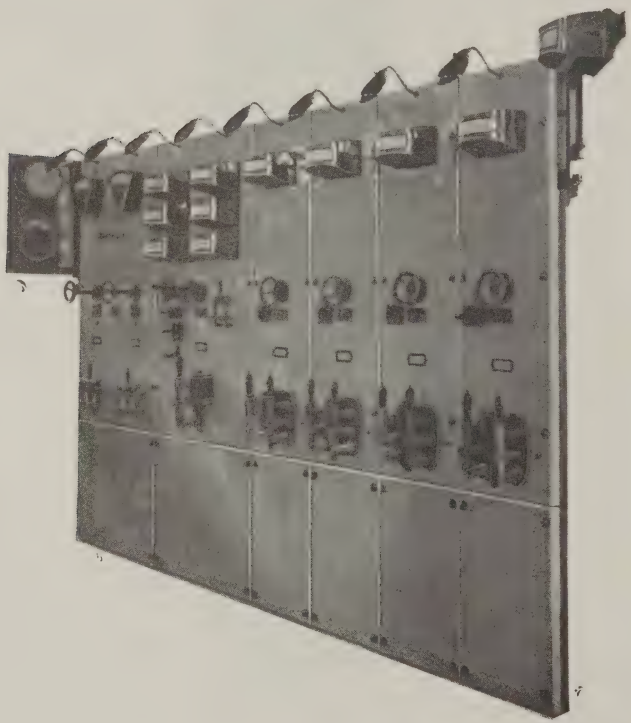

Fig. 18. Alternating-current switchboard for the Osaka Electric Light Company, Holden station.

the three-wire system, and a voltmeter for the three; the central section carries an overload or other relay for automatically tripping the switch under emergency conditions, and the switch-operating handle itself, and the third or lower section a recording integrating wattmeter.

It may be that in connection with this feeder there is no need for three ammeters, but one only; the system to be measured being balanced, in which case a different standard upper element would

be substituted with but one ammeter and one voltmeter. It may be that no voltmeter is necessary, but that an indicating wattmeter is desirable, in which case another upper standard element will be re-

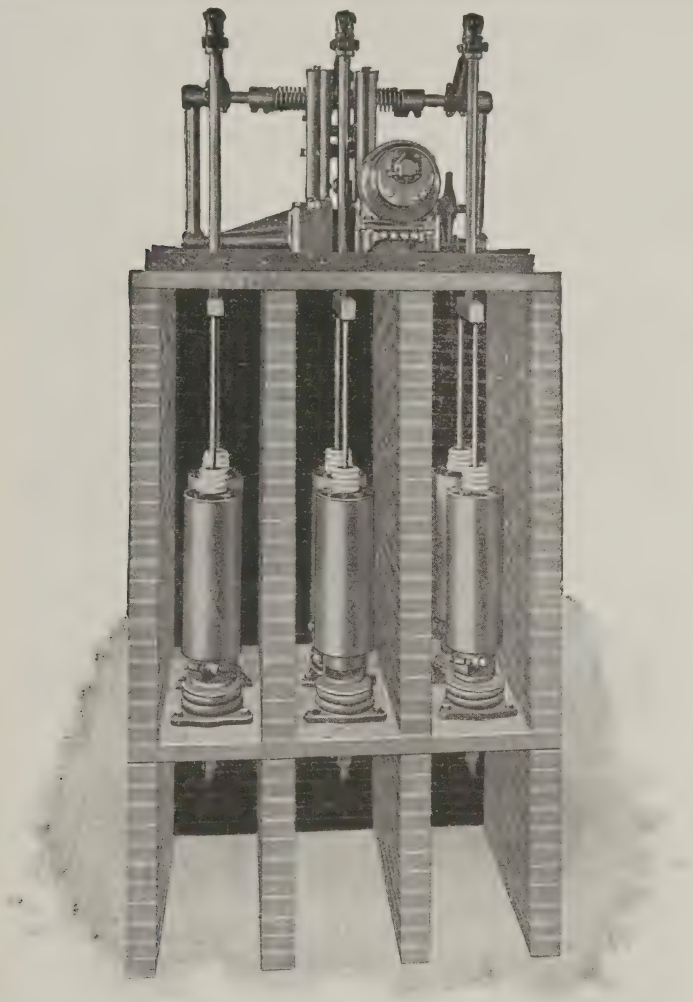

Fig. 19. High-tension oil switch with special cell. Litholite brick barriers.

quired, in connection with the central element. It may be that only a small hand-operated switch without automatic features is necessary, in which case a different standard central section will be required, quite interchangeable with the others, and if, in the

case of the third element, no recording wattmeter is desired or considered essential, a simple slab with no appliances may be substituted.

With this preliminary consideration of switchboard structures as complete devices, we reach the point where it becomes necessary to deal with the individual elements which come within the classification of switchboard devices.

These elements may be divided into six general groups:

1st. Switching devices, *i. e.*, appropriate structure for closing or opening circuits.

2nd. Safety or protective devices for automatically interrupting circuits under dangerous conditions, or under conditions such that continuity of the circuit is no longer desirable; typical of this class of devices are safety fuses, circuit-breakers and relays.

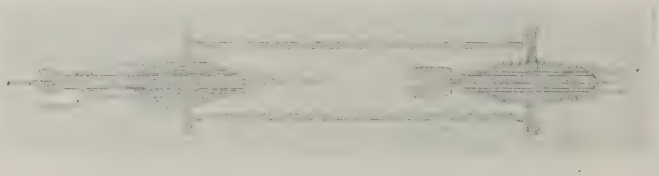

Fig. 20. 100,000-volt pneumatically operated oil switch.

3rd. Controlling or regulating devices, of which rheostats (most commonly field rheostats) and feeder regulators are the type.

4th. Instruments, of which the ammeter is the type.

5th. Ratio devices for use with instruments, such as shunt and potential transformers, and,

6th. Static discharge devices, of which the lightning arrester is typical.

These are the six groups within which we may class by their functions all the structures which are commonly to be found upon controlling boards.

The switch in its common form was, of course, the earliest of all these appliances and is often found physically associated or even combined with the simpler forms of safety devices, and in some cases control devices also.

An exceedingly simple form of primitive switch still thoroughly standard for low voltages, and especially upon direct current, is that shown in Fig. 13.

This is a standard three-pole direct-current switch, suitable for

use on a 220-volt, three-wire, direct-current circuit. This switch is physically combined with safety fuses of the enclosed type. The switch is complete in itself, but for quite obvious reasons it is convenient economically to combine the two structures and the two functions in one physical piece of apparatus. Switches of this type are the commonest in the art, and are found in capacities as high as 6,000 amperes, at which point the physical difficulties incident to opening and closing are beyond the strength of the average man.

When currents in excess of, say, 6,000 amperes are to be handled upon a single switch, switches generally take the form of a "butt

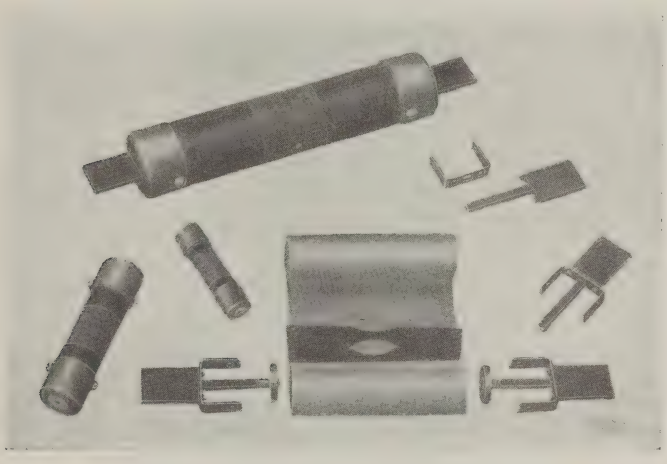

Fig. 21. Enclosed fuses and parts.

contact" device, similar in general structure to a circuit-breaker.

The amount of current to be handled alone determines the limit of the knife-blade switch in connection with all ordinary direct-current problems, which rarely require the engineer to deal with voltages in excess of 700 volts.

In alternating-current practice, however, where the voltage to be dealt with upon the switchboard is seldom less than 2,300, very commonly 6,600, and sometimes even 100,000 volts in American practice, the problem becomes a more difficult one.

To open a circuit under load at 13,000 volts, for example, with an ordinary knife-blade switch, is a fearsome thing.

In the writer's central station experience in 1888 we handled alternating-current energy on knife-blade switches with a long

break at a potential of 2,400 volts. These switches when pulled under load, as they often had to be, would draw a long humming arc of a most vicious nature. In these early days we had attached to the switchboard, at intervals, pieces of rawhide strap; these were taken in the left hand prior to pulling the switch, and the heavy arc drawn by the opening of the switch was extinguished by a sharp blow from the strap. This would not be possible at any voltage materially higher than two or three thousand volts.

Thirteen thousand volts is one of the most common of transmis-

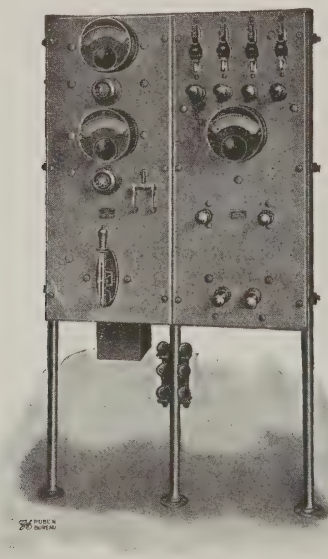

Fig. 22. A small plant alternating-current switchboard for an isolated installation not exceeding 2,500 volts. Expulsion fuses are shown.

sion potentials to-day, where current is to be carried for more than 8 miles. It may be regarded as a thoroughly standard voltage.

Fig. 14, for example, shows the effect of opening with a knife-blade structure a 13,000-volt circuit carrying 2,500 kilowatts (200 amperes). In this structure the arm or lever of the switch is 11 feet in length, the sweep of the arm, therefore, through a quarter circle is roughly about 18 feet, which may be set down as the length of the arc drawn in opening the circuit with this switch.

Contrast this crude device with the type of structure (Fig. 15) which is commonly used in the art in coping with such situations.

This illustration shows a standard oil switch such as is ordinarily

used for opening circuits of 100 amperes at 45,000 volts or, roughly, three times the potential of the air break 11-foot arm switch shown.

This is a three-pole switch, consisting actually of three single-pole switches, normally immersed in oil.

It is a well-known fact that the alternating-current arc will endure under oil for only the shortest of distances and this characteristic has been utilized, substantially to the exclusion of other methods, in handling the switching problem on high voltage systems.

The switch element on the extreme left is the switch complete,

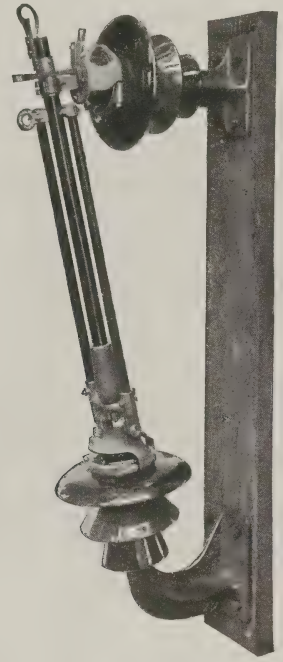

Fig. 23. Expulsion fuse, for 60,000-volt, 100-ampere, circuit.

with the oil pot in place; the central and right-hand elements have the oil pot removed. The lowest portion of the structure is the contactor, or bridge, which, when closed, is lifted into contact with the contacts shown at the bottom of the insulators, closing the circuit from one pole to the other. Such switches are readily accessible and are convenient, dependable and economical.

Such a switch, but for a lower voltage, is shown in Fig. 16.

Here we find a smaller structure for use on potentials of 2,500 volts, the most common alternating-current voltage. This voltage

does not necessitate the isolation of each pole of the switch in a separate structure, and they are accordingly grouped within one oil tank; the tank in this case has been removed and is not shown in the picture. The operating handle shows upon the face of the small panel which carries the switch. These alternating-current oil switches for the lower potentials are commonly mounted upon the back of the panel.

Fig. 17 shows a 2,300-volt switch designed for handling current up to 1,000 amperes, which is about the largest current capacity for which such switches are made.

That the physical method of control for switches of this kind

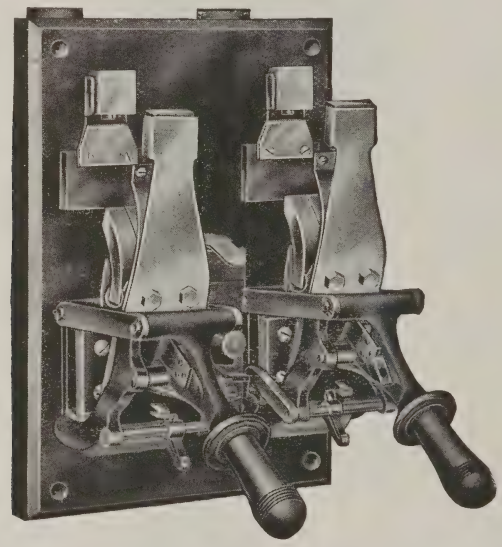

Fig. 24. A 1,200-ampere, 250-volt, double-pole circuit breaker.

may be more fully appreciated, the front of the switchboard is shown with a number of oil switch handles controlling switches of just the type illustrated. (Fig. 18.)

As the amount of energy to be controlled becomes larger, greater precautions become necessary in switch construction. The amount of energy to be handled becomes the point for consideration rather than the voltage. How to handle high voltages is a matter of mathematics; the length of the break is readily determinable and presents no peculiar difficulties. The handling and disruption of large energies, however, may be well likened to the handling of large explosive energies in ordnance. Each time that a switch is

opened a certain amount of material is volatilized, but the more quickly the arc is ruptured, the less the volume of gas generated.

To open a main feeder of the Interborough Railway System of New York, under full load, when a short circuit occurs on that feeder immediately outside the station, means, in general terms, that work must be done roughly comparable with that which would

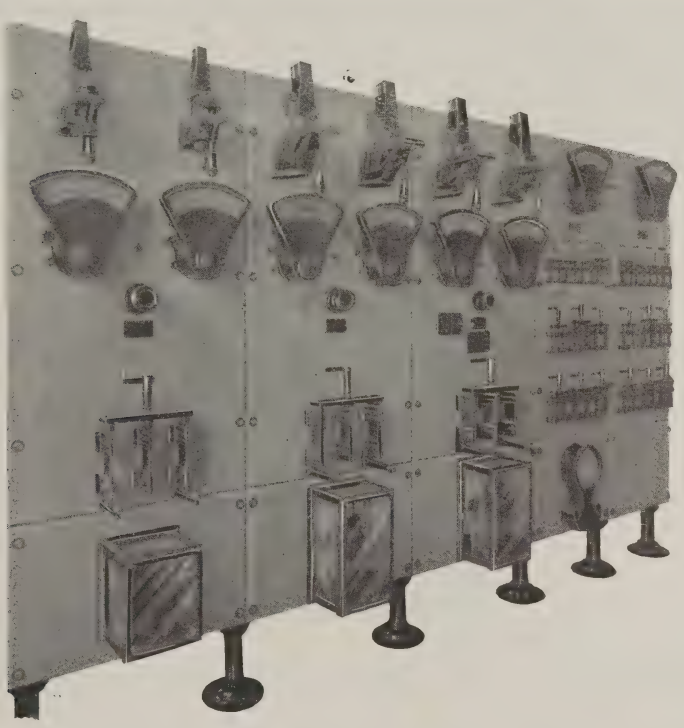

Fig. 25. Direct-current switchboard for Trinity Building, New York City, controlling 125-volt lighting system of the office building.

be expended in stopping the "Congressional Limited" in a distance of about 50 feet, when travelling at a speed of 60 miles an hour.

For such service, switches like that shown in Fig. 19 are used.

Each pole is confined in a substantial masonry cell with heavy doors. The switches are all grouped at a distance from the main operating board, and are controlled through motors by secondary or subsidiary switches. The control motors are tributary, in many cases, to automatic devices which will cause the switches to open of themselves in case of short circuit, either immediately or after

the lapse of a predetermined time, also, under other conditions, as, for example, when the voltage goes too low.

Perhaps the furthest development in switches of this general class as yet is the switch shown in outline in Fig. 20.

This is a switch structure differing only in detail from that just shown, but designed particularly for use upon systems of 100,000 volts for controlling energy to the amount of some thousands of horsepowers.

The central portion is an oil tank, the moving element a metal plug moving pistonwise through a stuffing box, and when closed passing into clips in an insulator at the opposite end of the tank. Such of these switches as are now in use commercially are 18 by 24

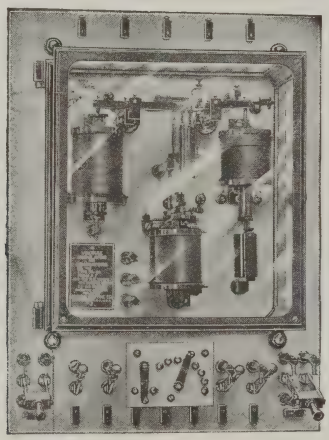

Fig. 26. The Tirrill regulator for maintaining a constant bus voltage and compensating for either inductive or non-inductive load fluctuations. It may be placed directly on panel or on brackets at the end of switchboard.

by 3 feet over all, weigh some 2,000 pounds per pole without supports and cost the user some $1,500.

One passes naturally from switches to protective devices, because these structures are so commonly combined.

The earliest form of protective device was, of course, the fuse. Somebody discovered, in the early days of the art, that by making a section of the circuit of a piece of wire considerably thinner than the remainder, any dangerously excessive current would cause that portion of the wire to melt away, and interrupt the circuit before the remainder of the circuit could become damaged. We see this same structure unchanged to-day where small amounts of energy are to be safeguarded.

But when large energies, even at low voltages, are to be dealt with, such structures do not suffice. The molten metal is considerable in quantity, and enough of it is volatilized when the short circuit occurs to scatter the remainder, thus constituting a fire menace.

This has led to the design of a series of structures known as enclosed fuses, which, in their simplest form, consist of wire packed in material calculated to absorb the gases and molten metal. As the duty becomes heavier, the character of the structure within the package changes and becomes more complex.

A common form consists of very thin metal rolled up like a surgical bandage, each turn protected from the other turn by suit-

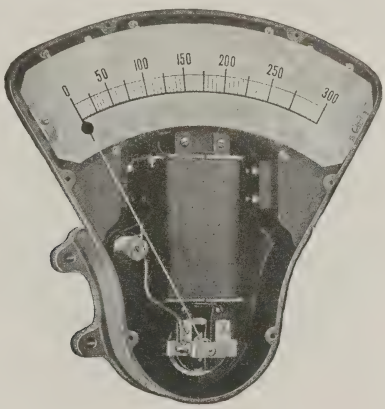


Fig. 27. Thomson illuminated dial astatic ammeter.

able insulating material, such as asbestos paper. Such a structure is shown in Fig. 21.

Here we have the least amount of metal for a given amount of conductivity, because of the greater radiating surface per inch of cross section. This means that the minimum of metal will be volatilized and the minimum amount of gas produced, a very diffuse arc is obtained and there is no concentration of rapidly expanding gases at any one point.

Such structures readily open a short circuit from a 1,000-kilowatt source.

But fuses are at best objectionable from the standpoint of convenience. They break admirably, to be sure, but they interrupt the circuit for a longer period than the present day conditions of operation will permit.

A fuse must be replaced, and before it can be replaced the circuit must be opened with a switch, and an interval must of necessity intervene before the continuity of the circuit can be reestablished. Consequently we find structures, in which mechanical means are provided for obtaining discontinuity of the circuit, coming into more common use daily.

Before we consider these, however, the highest development of the fuse is entitled at least to mention.

Some few years ago a form of fuse was developed which was known to those who introduced it as the "cannon fuse." The rapid volatilization of metal under the shock of sudden disintegration was recognized and utilized. A wire is passed through a cylinder or tube which may be likened to a gun barrel, save that it is of insulating material. The thinnest portion of this wire is located

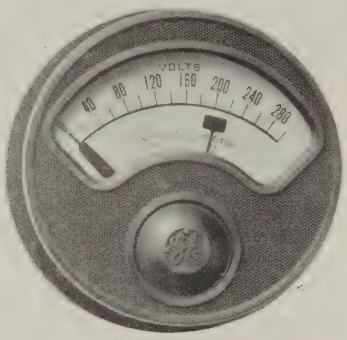


Fig. 28. This voltmeter, in capacities from 125 to 750 volts for direct-current service, is constructed on the D'Arsonval principle.

at the base of the barrel in the reinforced metal body, which is shown at the top of the switchboard in Fig. 22.

When a short circuit occurs, that portion of the fuse wire contained in the heavy metal bulb is instantly volatilized, and coughs forth the remainder of the wire from the muzzle, disrupting the arc. The phenomenon is accompanied by a somewhat loud report, and serves to remind the station attendant that a fuse needs replacing.

This is probably the highest development of the fuse, and in modified forms, as shown in Fig. 23, can be made to control large amounts of energy at very high voltages successfully and safely, this structure, for example, being designed for use at 60,000 volts, 100 amperes. It is a more economical method of protecting the

system than the automatic switch, but lacks the element of prompt restoration of the service, and is in all respects a cruder method of protection.

Of mechanically operated safety devices the circuit-breaker (Fig. 24) is the type.

The circuit-breaker in this illustration is a two-pole breaker, each pole being closed separately. In addition to the closing of the main contact which carries the current, a secondary and a tertiary contact are closed, the secondary being a light supplementary copper contact, closing before and opening just after the main contact, and the tertiary contact consisting of two carbon blocks, one fixed and the other movable, opening last, so that the final arc is drawn between carbon points or slabs, and does no harm by roughing or

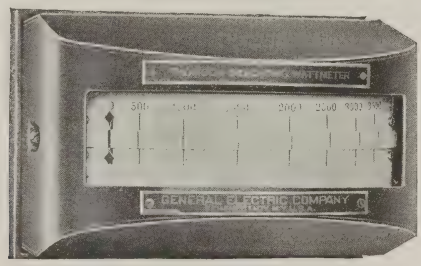


Fig. 29. Horizontal edgewise alternating-current wattmeter.

melting down the copper surface, which must be kept smooth and polished.

These structures are in all essentials switches, except they are so made that they trip open automatically, principally when the current of the circuit exceeds that for which they are set.

All sorts of supplementary tripping mechanisms are used on circuit-breakers; the standard overload coil is the most common, but we find also the low-voltage coil, which causes the breaker to open automatically when the circuit which it controls dies; this is especially valuable in connection with motors, for a motor must unavoidably be damaged if it is stopped and the full current is restored to it without the rheostat having been adjusted.

It is well to call attention to that feature of the circuit-breaker which makes the two or more poles independent. This makes it possible for a circuit which has just been thrown open by an overload or short circuit to be immediately closed without fear by the

attendant. He throws in one pole, but the circuit is still dead; he then throws in the second pole. If the overload or short circuit is still on the system, the free pole trips out without damage to the operator or the system.

Practically all of the larger circuit-breakers in use to-day are of the carbon-break type. From such breakers there is, of course, a flash upon opening, sometimes of considerable magnitude. For this reason there is but one safe and proper place at which to install circuit-breakers, and that is at the extreme top of the switchboard panel where the flash can not do harm, where a short circuit can not be conveyed to wiring, where the face of the board can not be marred, and where the eyebrows and eyes of the operator

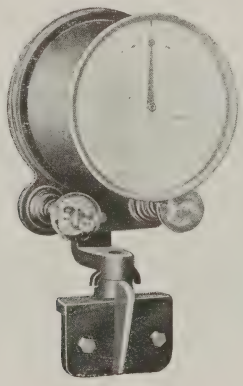

Fig. 30. The synchronism indicator is standardized for operation on from 100 to 600 volts, and from 25 to 60 cycles.

can not be injured. A series of circuit-breakers correctly located is shown in Fig. 25.

The oil switches which I have shown are generally so combined with automatic relays as to render them switches and circuit-breakers in one. The smaller types open by gravity, whilst the larger ones are operated both in closing and opening by a motor.

Under control devices we find three general classes of structures in common use:

1st. The rheostat, a device for placing a variable amount of resistance in the circuit. Such structures are very familiar and seem to require neither illustration nor description, which could not be undertaken without going into great detail.

2nd. Regulators, or rather, feeder regulators, which are used for increasing or decreasing the voltage of the feeder in such a

manner as to maintain the pressure at that required for the best light and power service are made both upon the inductive principle for alternating systems, and in the rheostat form in modified types.

(I venture, however, to refer those interested particularly in such structures to the paper which it was my privilege to read last year to the class of 1907 [Occasional Papers, Engineer School, No. 26].)

3rd. There remains one type of regulator deserving of brief mention, commonly used and well illustrated in Fig. 26.

This is the so-called Tirrill regulator, not used as a feeder regulator, but as an automatic generator regulator.

It consists elementally of a movable element, comparable with the telegraph receiver, which is moved into and out of contact with con-

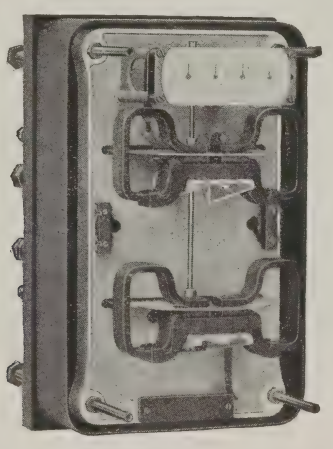

Fig. 31. A polyphase recording wattmeter.

tact points by a coil or coils responding to fluctuations in the voltage, opening when the voltage becomes too high and closing when it becomes too low, the contactor serving to cut in and out sections of resistance in the field of the exciter, thereby varying the excitation of the generator and its voltage. These structures serve admirably to keep the voltage at practically normal, under conditions of even extreme fluctuation of both speed and duty.

In the class of instruments we find a subject vastly too large by itself to be more than briefly referred to in the scope of a paper of this kind.

The ammeter is perhaps the most common and most typical of

instruments. Its function is well known to all of you, and it was without doubt the first instrument used upon switchboards.

The mechanisms which are commonly used for the moving elements of indicating instruments are exceedingly varied. Some fifty or sixty mechanical or electro-mechanical principles have been resorted to and a dozen or more have resulted in highly successful structures. No attempt, therefore, will be made to go into the characteristics of the actuating mechanism.

A typical ammeter for heavy duty on direct current is shown in Fig. 27.

The instrument is shown with the cover removed and serves very well to illustrate the general delicacy of the moving elements, which

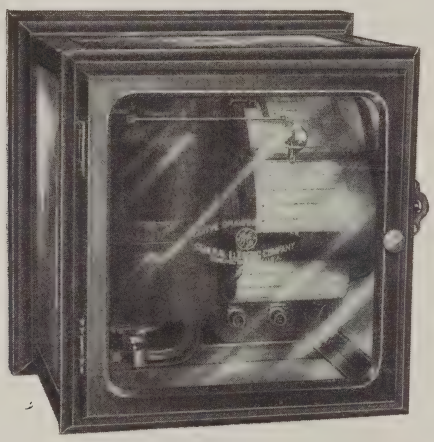

Fig. 32. Direct-current curve drawing ammeter.

are resorted to in almost all the high grade instruments. In this particular instrument the scale is made upon translucent porcelain and incandescent lamps being used behind the scale to make it easy to read under adverse conditions.

The voltmeter is, of course, essentially a switchboard instrument. It serves to tell instantly whether the pressure is that for which the system has been designed and whether the service given upon the lines is effective. A typical voltmeter of one of the most common types in general service is shown in Fig. 28.

The indicating wattmeter is used very generally upon alternating-current systems, where the ammeter and the voltmeter readings, multiplied one by the other, do not necessarily give the true

watts or power output because of the lag upon the system, which may be under some conditions considerable. Indicating wattmeters are substantially never seen upon direct-current systems, but inversely are substantially universal upon alternating-current systems.

The typical instrument of this class is that shown in Fig. 29.

In this instrument there are, of course, involved two electrical elements: a coil, the strength of which is, of course, dependent upon the current, and a coil, the strength of which is dependent upon the pressure, the strength of one fluctuating with the current and the other with the voltage and the influence of one coil upon the other—that is, the concurrent strength of the two coils—causes the needle to take a given position on the scale.

This picture serves also to illustrate a proper and very common type of scale, known as the horizontal edgewise scale, and generally regarded as easier to read with accuracy than the segmental scale, quite common up to a few years ago. It is needless to say that in-

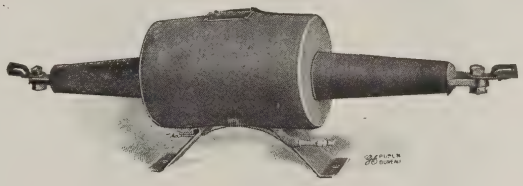

Fig. 33. A switchboard current transformer.

struments with horizontal edgewise scales are also made in the form of ammeters, voltmeters, and other instruments, and this is true also of the vertical scale instruments developed by Weston, and also segmental scale instruments.

Other instruments which will commonly be found upon large alternating-current switchboards are power factor indicators, indicating the percentage of power factor—that is, the decimal by which to multiply the apparent volt-amperes to obtain the actual watts or power—the frequency indicator, which indicates the cycles or alternations per second, and constituting a good check upon the speed of the generating apparatus, and synchronism indicators or synchronoscopes.

The synchronoscope is of somewhat recent development, and is found substantially in all stations where two or more alternating-current generators are operated at times in multiple. It is well illustrated in Fig. 30.

Its function is to enable the operator to tell when the second generator can be thrown in to the system by closing the main switch, without being in opposition to the other machine and at a different or non-synchronous speed, which would be rather dangerous.

The synchronoscope is switched in and attached to the machine on the bus-bars and the machine to be thrown in; the indicating

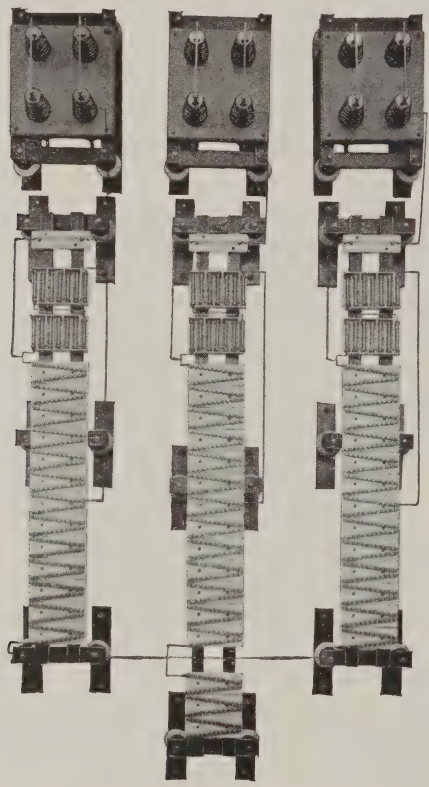

Fig. 34. 35,000-volt, three-phase, multiplex, lightning arrester, with double-blade disconnecting switches for Y-connected, neutral-grounded circuits.

needle rotates in one direction if the machine to be thrown in is too slow; in the opposite direction if it is too fast. The switchboard attendant watches until the speed becomes synchronous, and the needle comes to rest, indicating that the machines are similar and not in opposition; the switch is then thrown in and the machines tied together.

In addition to indicating instruments, one finds upon many

switchboards both recording (graphic) and integrating recording instruments. The integrating meter takes many forms, of which Fig. 31 is typical, and serves, like the well-known gas meter, to record on a dial the number of units of electrical energy which have passed through it during the period of its use. The use of such

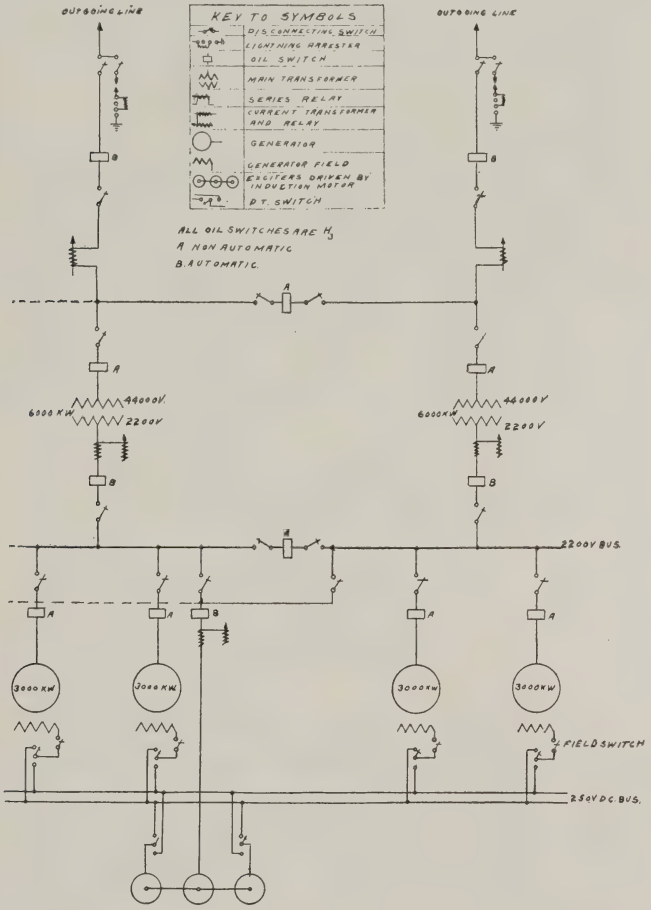


Fig. 35. One-line wiring diagram, Ninety-nine Island station.

instruments is quite obvious, and there are probably not less than two million such structures in use in the United States to-day.

The graphic type of recording instrument is a structure of somewhat greater refinement, giving a chart of the fluctuations upon the system, of the current output, of the voltage variation or

of watts delivered, according as the instrument may be designed and used for the recording and measuring of volts, amperes or watts. Such a device is shown in Fig. 32.

A four-inch ribbon of paper feeds at a predetermined rate, say, one inch per hour, through the machine, and across its surface a fountain pen is carried by an arm, the position of which is determined by the amount of current or the pressure of the wattage, as impressed upon the instrument by the system to which it is connected.

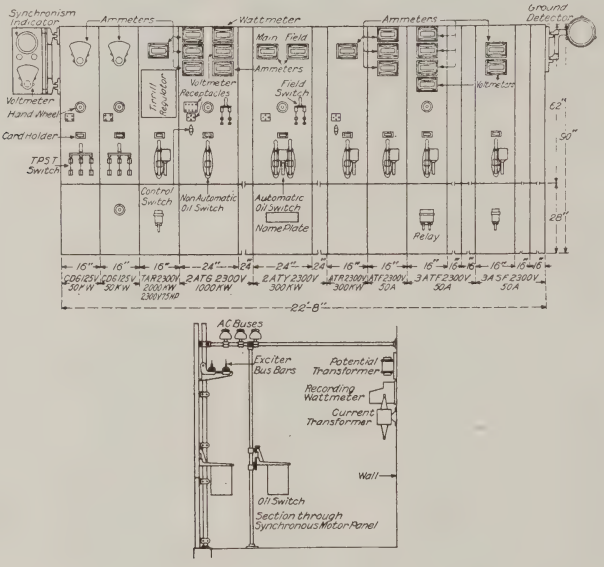


Fig. 36. Typical 2,300-volt, three-phase, switchboard.

In connection with most instruments ratio devices are used; very commonly in direct-current ammeters, for example, the shunt is used. It consists of a simple structure of known resistance, generally a very small resistance, which forms a part of the conductor, and the drop or fall of potential around it is impressed upon the actual indicating instrument. This drop, of course, fluctuates with the current upon the system, and by the use of the shunt the necessity for carrying heavy and costly leads to and from the switchboard is obviated.

On alternating-current circuits we find the current transformer taking the place of the shunt, the main circuit passing through the primary of the current transformer, and the instruments proper

being served by the current impressed upon the secondary by induction from the primary. This not only obviates conducting the main leads to the instrument, but also makes it possible to take leads to the instrument carrying a voltage which is not harmfully

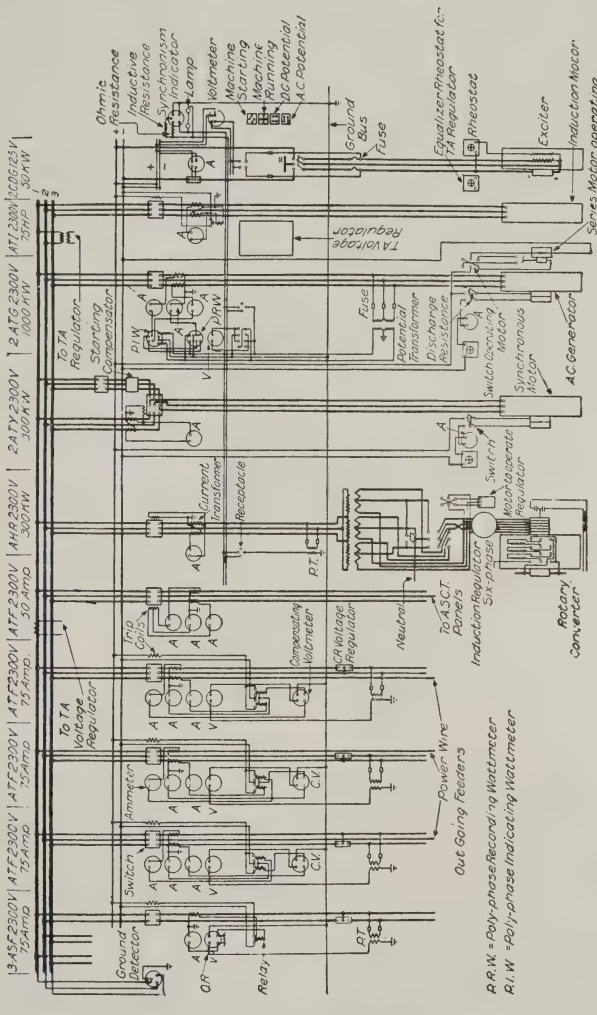


Fig. 37. Wiring diagram for typical 2,300-volt, three-phase, switchboard.

high, instead of a potential which might be deadly in case of accident.

Such a current transformer is shown in Fig. 33.

In direct-current voltmeters a fixed resistance is placed in series

with the actuating mechanism to prevent too much current going through the voltmeter, the voltmeter being in reality an ammeter measuring very small current values, this current being dependent upon the fluctuations of the voltage through the resistance. In alternating-current service the potential transformer takes the place of the resistance, the primary across the potential of the system, impressing the fluctuations in the potential of the system upon a lower voltage secondary, which carries no other load than the instrument or instruments upon it.

For those who wish to make a more academic study of the electrical instrument art, which is indeed a subject quite by itself, I venture to make reference to my paper before the International Electrical Congress at St. Louis, published in the proceedings of that congress in 1904.

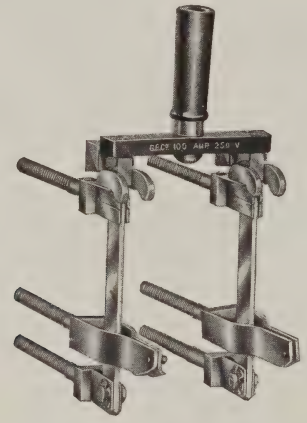

Fig. 38. Field switch with discharge clips and resistance.

There remains just one more class of structures used upon switchboards to be mentioned—devices for discharging sudden static disturbances or excessive stress, as in the case of lightning discharges or static accumulation upon the system.

If means for this "slopping over" of the system were not provided the high potentials impressed upon the system by direct lightning stroke, or by induction, without being free to go to ground or from one leg of the system to the other, would break down insulation, cause short circuits and destroy almost any complex system. We are, in short, dealing with voltages so considerable as to be able to establish arcs many feet in length, even hundreds of feet; in short, we are dealing with the lightning flash.

There are dozens of forms of lightning arresters; perhaps as typical a form as any is that shown in Fig. 34.

Whatever their general form may be, it will be found that they are based upon a single principle, a structure which will, when placed between line and ground, or between line and line, not permit the passage of any current under the normal potential of the system, but which will break down, by the jumping of the spark or sparks under extremely abnormal voltages, and permit the static conditions to regain their balance, but which, nevertheless, will not, in so doing, establish an arc across the system which will constitute a short circuit when the static phenomena cease.

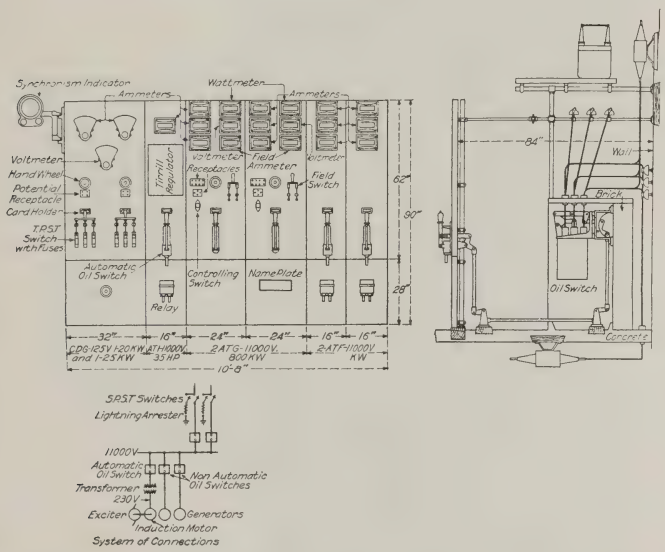


Fig. 39. A 11,000-volt, alternating-current, switchboard for two three-phase, engine-driven, generators, one engine-driven exciter, one induction-motor driven exciter, and two high-tension feeders.

The common way to provide for this is to place a number of minute air breaks in series, and in series with the line, so made up as to place a number of high resistances, so considerable as to forbid the passage of current enough at normal voltage to sustain an arc. Such a structure is that here shown.

In these days the switchboard is not normally made to carry the lightning arresters, but in some cases they are placed upon or directly behind the board; they are, however, generally regarded as a switchboard device or directly tributary to the switchboard.

And now one final word as to the laying out of the preliminary plan for the switchboard, or for the complete system, a piece of work which any engineer may be called upon to do at any time.

Until very recently it has been the custom to lay out wiring plans or schemes, two-wire, three-wire, or four-wire, single, three-phase

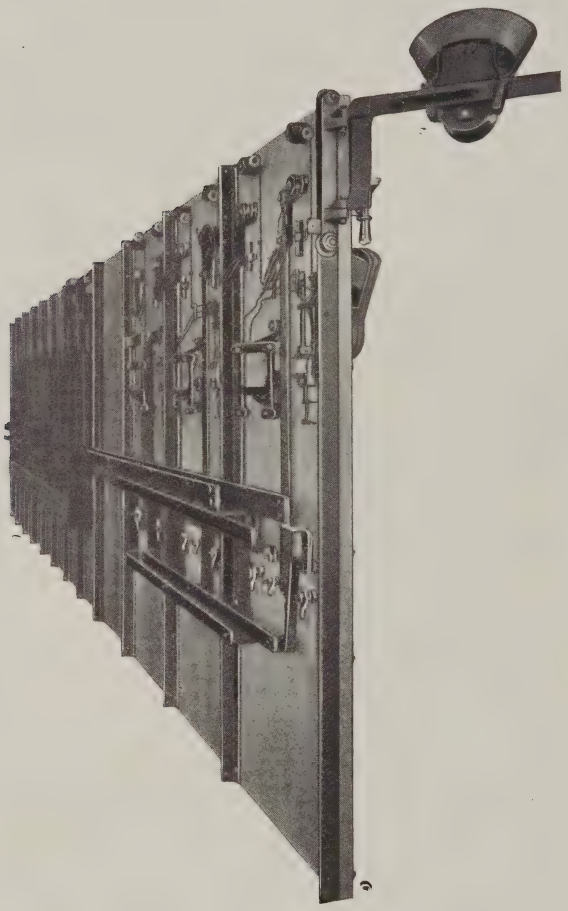

Fig. 40. Back view of a 600-volt, direct-current, switchboard for power service.

or quarter-phase, as conditions may demand, with all the complexities of crossing wires which render a diagram a maze before it is half completed.

Good modern engineering no longer tolerates this, and it is the usual practice to lay out all systems in general on the one-line basis, working out details only with return wires.

A typical one-line wiring diagram, constituting the complete layout for a modern 1,200 kilowatts central station, switchboard and all, is shown in Fig. 35. It tells all that the engineer needs to know as to the preliminary geography of his plant, and constitutes a quick and thorough means of tracing every element of his system and locating it.

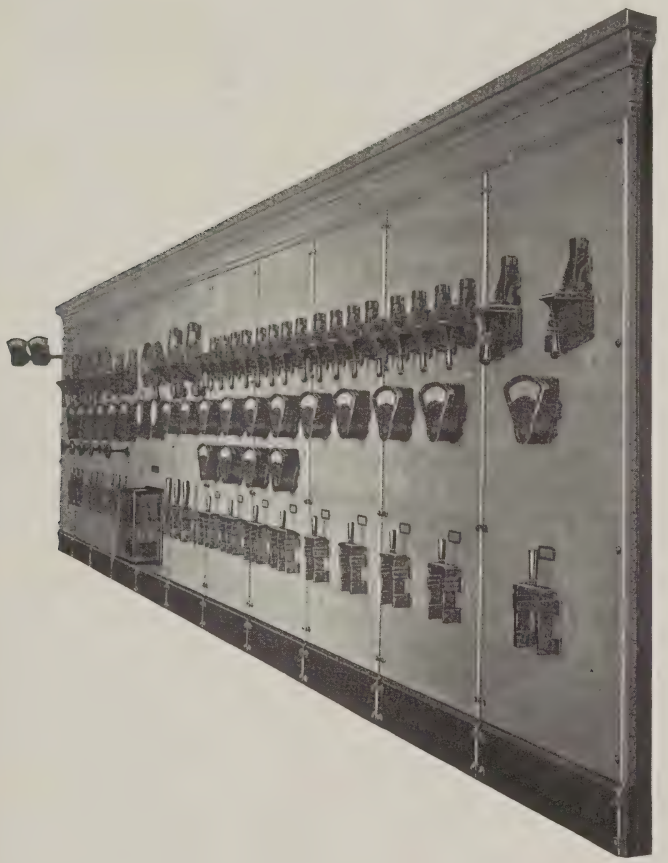

Fig. 41. Front view of a 125-250 volt, direct-current, switchboard, arranged for Edison three-wire service.

This diagram will be useful as a guide to quick and accurate engineering plans, and the conventional symbols used are those now common for work of this character.

I am appending to this paper a series of notes recently prepared for the general guidance of engineers in the field in the construc-

tion and design of ordinary moderate capacity alternating-current switchboards. It is not my intention to read it here, since in many respects it serves as a synopsis of what I have already stated at more length; as an appendix to this paper, in printed form, it may, however, be of considerable use, taken into consideration with the illustrations covering it.

No effort has been made to cover direct-current switchboards in this appendix, as they are generally considerably less complex than alternating-current switchboards.

A GUIDE TO THE DESIGN OF MEDIUM AND SMALL CAPACITY CENTRAL STATION SWITCHBOARDS.

*For Alternating Current.*

In consulting a guide for the design of switchboards, it must be borne in mind that every switchboard is to a certain extent special, as the conditions, of course, vary in different stations. With the information given in the following pages it should be possible, however, to make an arrangement of panels to suit practically any existing conditions.

The facts given herein represent the latest practice in designing switchboards for the moderate sized station, and an effort has been made to take only representative cases, to discuss these cases thoroughly and to point out the features which are most to be desired, and also those features which should be avoided.

Two types of switchboards are described—one for 2,300 volts, which is the customary voltage for the average central station, and one for 11,000 volts, which represents the average small, water-driven generator plant or steam plant for transmitting energy to some distant point. The 2,300-volt switchboard will be described first. Fig. 36 is the front view of such a board, while Fig. 37 is the wiring diagram of a similiar board, but not the same board.

2,300-VOLT ALTERNATING-CURRENT SWITCHBOARD.

*Exciter Panels.*

Exciter panels should preferably be arranged for the control of only one exciter for many reasons:

1st. The panel and the exciter can be considered as a unit, and can be disposed of together if any change is made in the equipment.

2nd. A much more symmetrical arrangement can be made of the instruments and devices.

3rd. It often means that the switchboard can be laid out with a fewer number of sizes of panels.

The equipment recommended for exciter panels is as follows:

One ammeter.

One field rheostat.

One double-pole, single-throw, fused switch.

One two-point potential receptacle.

Negative and equalizer switches should be mounted near the machines.

### INDUCTION MOTOR PANEL.

When exciters are driven by induction motors, it is necessary to provide a panel for the control of the motor. The equipment should consist of the following:

One ammeter.

One triple-pole, single-throw, automatic oil switch.

One inverse time-element relay.

In almost all new plants a Tirrill regulator (see Fig. 26) is installed, and if there is room on this panel, the regulator is installed here.

This arrangement is used also because the induction motor panel is usually placed between the exciter panels and the generator panels. If for any reason the induction motor panel is not so placed, it is better to use a separate panel for the regulator.

### VOLTMETERS AND EXCITERS.

The best plan is as a rule to use one voltmeter for the exciter, and mount this on a bracket at the end of the board. It can be of either the feeder type or the illuminated dial type.

If a voltmeter is used for each exciter it can be mounted on the exciter panel, the potential receptacle then being unnecessary.

### GENERATOR PANEL.

The standard equipment of a three-phase generator panel is as follows:

Three ammeters.

One polyphase indicating wattmeter.

One voltmeter.

One field ammeter.

A double-pole, single-throw, field switch with discharge clips and resistance.

One handwheel for field rheostat.

One four-point synchronizing receptacle.

One eight-point potential receptacle and four-point plug.
One triple-pole, single-throw, non-automatic, oil switch.
Two current transformers.
Two potential transformers.

Since generators are usually rated in current output, it is advisable to install ammeters on these panels so that it will be possible to ascertain at once exactly what current the machine is delivering. All three-phase systems are more or less unbalanced; therefore, in order to obtain correct readings it is necessary to install an ammeter in each leg.

Indicating wattmeters are very important, as it is not possible to determine by any other means the division of load between two alternating-current generators running in multiple. The ammeters do not differentiate between the idle current and the line current from the machines, and thus are of no use in determining the division of load.

Field ammeters are very useful, but not absolutely necessary. They serve as a check on the generator in case of any trouble, and are invaluable at the times of testing for troubles.

Voltmeters are, of course, used to read the voltage of the machine before it is connected in multiple with any other. They are also used to indicate the potential of the busses. The eight-point receptacle on the panel is used to read the potential of any of the phases with one voltmeter.

The field switch (Fig. 38) is provided with discharge clip and resistance, in order that the inductive discharge which occurs when the switch is opened can be taken up and dissipated without injury to the machine or any of the other apparatus.

The synchronizing plug is used to connect the generator to the synchronizing busses leading to the synchronism indicator.

Synchronizing between machines is to be recommended and for this reason two types of plugs are furnished for this purpose; one is marked "machine running," and the other "machine starting." If a synchronism indicator (see Fig. 30) is used, the proper connections will be made by means of these plugs, so that the synchronism indicator will indicate properly whether the incoming machine is operating too slow or too fast.

Usually the rheostat is too large to mount back of the panel. The handwheel can be mounted on the panel and connected to the switch on the rheostat by means of a sprocket wheel and chain or

bevel gears, etc., or in some cases the dial switch of the rheostat can be placed on the panel and connected to the resistance by leads. The latter arrangement is objectionable, on account of the great number of leads and the expense. If rheostats are placed at any considerable distance from the switchboard, it is better to operate them electrically and mount simply the control switch on the panel.

Where panels are furnished for turbine-driven generators of above 500-kilowatt capacity, a double-pole, double-throw, engine-governor control switch is furnished for controlling the synchronizing motor on the governor.

Many engine builders furnish motors to operate the governors of their engines, and it should be ascertained in each case whether such a device is to be furnished and the type of motor used, in order that the proper switch can be mounted on the panel.

No automatic protection is recommended for alternating-current generators for several reasons:

1st. If automatic switches are used, there is great danger of shutting down the plant at the time of synchronizing, if the machines are not exactly in synchronism when they are connected together.

2nd. If a short circuit or overload occurs on any feeder, the generator switches are liable to open at the same time as the feeder switches, thus causing a shut-down.

3rd. Most alternating-current generators are so designed that they are not injured if they are momentarily short circuited.

### SYNCHRONISM INDICATOR.

A synchronism indicator is recommended in all cases, and the best place for it is on a swinging bracket placed at the end of the board.

### SYNCHRONOUS MOTOR PANELS.

When motor-generator sets are used for furnishing either Edison three-wire, direct-current service, or 600-volt railway or power service, the synchronous motor panels should be equipped with:

One main ammeter.

One field ammeter.

One double-pole, single-throw field-switch, with discharge clips and resistance.

One rheostat handwheel.

One triple-pole, double-throw, automatic oil switch (automatic on one throw only).

One triple-pole, single-throw, oil switch for compensator.

Two current transformers.

If the synchronous motor sets are started from the direct-current side, the main switch is made single throw. If, however, they are started from the alternating-current side, the main switch should be made double throw, in order that the motor can be connected to the starting taps on the compensator and then thrown over to the line by the switchboard operator.

When the sets are started from the direct-current side, it is necessary to synchronize and to add a voltmeter and potential transformer to the panel for reading the potential when synchronizing.

The arrangement of the field rheostats on these panels should be similar to the arrangement of the rheostats on the generator panels.

### ROTARY CONVERTER PANEL.

In case rotary converters are used in place of motor-generator sets, the alternating-current panel should have the following equipment, assuming direct-current start:

One main ammeter.

One synchronizing receptacle.

One triple-pole, single-throw, automatic, oil switch.

Two current transformers.

One potential transformer.

When rotary converters are used for furnishing Edison three-wire service, it is customary to install a regulator on the alternating-current side of the rotary, in order to be able to control the potential of the direct-current service. This regulator is usually made motor-controlled, and in such cases a double-pole, double-throw switch should be mounted on the panel. When the sets are started from the direct-current side, it is necessary to add a voltmeter and a potential transformer to the panel for reading the potential when synchronizing.

### THREE-PHASE FEEDER PANELS.

Three-phase feeders are frequently used for lighting, but are more generally used for power service, and the equipment of the panels should consist of:

Three ammeters.

One triple-pole, single throw, automatic oil switch.

Two current transformers.

If three-phase feeders are used to supply light as well as power, the preferable method for operating the lighting circuits is to connect the lights to one phase of the three-phase feeder and insert a

regulator in this phase; thus complete control can be had of the lighting. The usual equipment of a panel for controlling a circuit of this kind is as follows:

Three ammeters.
One voltmeter.
One handwheel for the control of the regulator.
One triple-pole, single-throw, automatic oil switch.
Four current transformers.
One potential transformer.
One voltmeter compensator.

If the regulator is located at a considerable distance from the switchboard, it is preferable to operate it electrically, and a double-pole, double-throw control switch, instead of the handwheel, should be mounted on the panel. If the regulator can be placed close to the panel, however, it can be connected to the handwheel on the panel by means of either a sprocket wheel and chain, or by beveled gears.

### SINGLE-PHASE FEEDER PANEL.

If single-phase feeders are used for lighting, the equipment should be as follows:

One ammeter.
One voltmeter, compensating type.
One double-pole, single-throw, automatic oil switch.
One current transformer.
One potential transformer.

In case regulators are used, the same arrangement should be made on this panel for the control of them as is outlined for the panels given in the foregoing item.

### GROUND DETECTORS.

It is desirable to furnish an electrostatic ground detector for the bus-bars. This can be mounted on a stationary bracket at the top of the board or on a swinging bracket at the side of the board. The bracket at the top of the board is preferable, as it places the instrument beyond the reach of the station attendant, thus removing all high-tension apparatus from the switchboard proper.

### ARRANGEMENT OF APPARATUS.

There are many arrangements possible for the oil switches, current and potential transformers, bus-bars and connections, etc.

These arrangements are all dependent upon the design of the station and the proposed location of the switchboard.

Fig. 39 shows the bus-bars mounted on a pipe framework at the top of the panel and the oil switches on the panel pipe supports. The use of remote control switches makes a preferable arrangement, as it thus brings the connections in such a position as to make the backs of the panels accessible for testing, or for any changes or repairs which are found necessary.

Under no condition should the current and potential transformers be mounted on the backs of the panels, as when so mounted the whole back of the panel is covered by the connections to and from the transformers, and is thus made inaccessible, and in many cases the connections are so crowded as to make it unsafe. The preferable arrangement for these transformers (see Fig. 39) is to install the current and potential transformers in the leads from the generators beneath the floor, if the leads come in from below, or on the wall in case they come from above. Transformers connected to the feeder circuits, however, should be mounted on the wall if the feeders go out above, or beneath the floor if they go out underground.

Figs. 36 and 39 show a number of different arrangements of bus-bars and switches which can be used.

### RELAYS.

There has been developed a form of relay which is called the Bellows type relay. This relay operates on the inverse time-element principle—that is, it can be adjusted to operate in a predetermined time with certain currents. If so adjusted, the time of operation is inversely proportional to the amount of current, and approaches an instantaneous value in case of a short circuit. The use of these relays is recommended on all feeder circuits, alternating-current rotary converter panels and synchronous or induction motor panels, as it prevents the shutting down of the circuit in case of a momentary overload, yet will instantaneously disconnect the circuit in case of short circuit or similar trouble.

### DIRECT-CURRENT SWITCHBOARDS.

Fig. 40 shows the back view of a switchboard, which is arranged for direct-current, 600-volt, power service, and Fig. 41 shows the front view of a switchboard arranged for 250-volt, Edison, three-wire service.

### 600-VOLT POWER SWITCHBOARD.

*Generator Panel.*

The panel shown in Fig. 40 is exactly the same, whether used with a rotary converter or a generator driven by a synchronous or induction motor or an engine, excepting that no field switch is provided for converter panels.

The equipment of this panel should be:

One circuit-breaker.
One ammeter.
One handwheel for rheostat.
One double-pole, single throw field switch, with discharge clip and resistance.
One four-point potential receptacle.
Two single-pole, single-throw lever switches.

If machines are equipped with speed-limit devices, it is customary to provide low-voltage release coils on the circuit-breaker.

If the generator is a part of a motor-generator set and is to be arranged for direct-current starting, a four-throw starting switch should be mounted on this panel.

The alternating-current panels used for the control of the motor, if the generator is motor-driven, are described under the heading of the alternating-current switchboard.

### FEEDER PANELS.

The equipment of the feeder panels should consist of the following:

One single-pole circuit-breaker.
One ammeter.
Two single-pole, single-throw main switches.

### VOLTMETER.

One voltmeter should be mounted on a swinging bracket placed in some convenient location. This voltmeter can be of either the feeder type or illuminated dial type.

### 250-VOLT THREE-WIRE SWITCHBOARD.

*Generator Panels.*

Fig. 41 shows two direct-current generator panels; one is for the control of two low-voltage machines run in series, for furnishing 250-volt three-wire service, and the other is the direct-current

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panel of a rotary converter. The panel for controlling the two direct-current, low-voltage machines would be exactly the same for either an induction or a synchronous motor-driven set, and should have the following equipment:

Two circuit-breakers.
Two ammeters.
Two handwheels for field rheostats.
Two double-pole, single-throw field switches, with discharge clips and resistances.
Two four-point potential receptacles.
Three single-pole, single-throw lever switches.
One four-point starting switch.

If the two generators are driven by an engine, of course the starting switch can be omitted.

DIRECT-CURRENT ROTARY CONVERTER PANELS.

The direct-current rotary converter panel should have the following equipment:

Two circuit-breakers.
Two ammeters.
One handwheel for field rheostat.
One four-point potential receptacle.
Two single-pole, single-throw lever switches.
One four-point starting switch.

It is generally preferable to start either rotary converters or motor-generator sets from the direct-current side, as this causes much less disturbance to the system, which, of course, is important for lighting work. The foregoing panels are arranged for shunt-wound generators and shunt-wound rotaries, as these machines are usually furnished for lighting. If, however, compound-wound machines are furnished, equalizer busses should be placed near the machines, and the equalizer switches on either the frame or a pedestal adjacent to the machines.

In the case of the two machines running in series it is necessary to have the series fields of the machine operating on the positive side of the system connected in on the positive side of the machine. The machine operating on the negative side of the system should have the series field connected in on the negative side of the machine; the circuit-breakers should be connected in the leads running to the neutral. The reason for this is that the neutral is usually grounded, and as only one circuit-breaker is furnished for each machine, it is advisable to have this connected in on the side

of the machine which is grounded, in order to properly protect the machine against a ground in the leads from the machine to the switchboard, or on the machine itself.

### FEEDER PANELS.

The feeder panels shown in Fig. 3 are each arranged for one three-wire circuit. These panels should be equipped with two circuit-breakers, two ammeters and two single-pole, lever switches.

There should be installed on one of these feeder panels a six-point receptacle, in order that the potential can be read between each leg of the system and the neutral.

There should also be installed a four-point receptacle for reading the potential across the outside of the three-wire service.

### VOLTMETER.

There should be furnished a voltmeter mounted on swinging bracket. This voltmeter can be of either the feeder type or illuminated dial type. This bracket can be mounted at either end of the board.

### 11,000-VOLT ALTERNATING-CURRENT SWITCHBOARD.

Fig. 39 illustrates a switchboard designed for two three-phase, 11,000-volt, engine-driven generators, one engine-driven exciter, one induction-motor-driven exciter, and two high-tension feeders.

### EXCITER PANEL.

The exciter panel is arranged to control two exciters, in order that a direct comparison may be made between a panel controlling two exciters and the two individual exciter panels described under the head of the low tension, alternating-current switchboard. The exciter panel has the following equipment:

Two feeder type ammeters.
One feeder type voltmeter.
Two rheostats.
Two two-point potential receptacles.
Two triple-pole, single-throw switches with fuses.
One equalizing rheostat.

TIRRILL REGULATOR PANEL.

This panel should have the following equipment:

One Tirrill regulator.

One potential transformer.

Above regulator equipment is suitable for maintaining constant bus voltage. If compounding is desired, one current transformer is necessary.

INDUCTION MOTOR PANEL.

The induction motor panel should have the following equipment:

One horizontal edgewise ammeter.

One set of three single-pole, automatic, oil switches, operated as a triple-pole switch.

One time-limit overload relay.

Two current transformers.

TWO GENERATOR PANELS.

Each generator panel should be equipped with the following:

One horizontal edgewise ammeter.

One polyphase indicating wattmeter.

One horizontal edgewise voltmeter.

One horizontal edgewise field ammeter.

One double-pole, single-throw field switch, with discharge clip and resistance.

One four-point synchronizing receptacle

One handwheel for field rheostat.

One double-pole, double-throw, engine governor control switch (optional).

One set of three single-pole, non-automatic oil switches, operated as a triple-pole switch.

Two current transformers.

Two potential transformers.

TWO FEEDER PANELS.

Each feeder panel should be equipped with the following:

Three horizontal edgewise ammeters.

One set of three single-pole, automatic oil switches, operated as a triple-pole switch.

One time-limit overload relay.

Two current transformers.

In addition to the foregoing there should be a synchronism indicator mounted on swinging bracket.

There should also be provided for each line a set of lightning arresters with double-blade, disconnecting switches, one blade of which is used to disconnect the lightning arrester, and the other to disconnect the line.

The arrangement as shown in the illustration is for a small station, and shows the bus-bars mounted on a pipe framework near the top of the board, and the oil switches mounted in brick compartments back of the board. This arrangement is not the best for stations of large size, as best practice places the bus-bars in a separate brick compartment. This can be placed back of the board, if there is sufficient space, or the switches and bus-bar compartment can be mounted beneath the floor in the basement.

### MATERIAL OF PANELS.

The standard material for 1,150 and 2,300 volt alternating-current switchboards with primary instruments is blue Vermont marble. When all the instruments are secondary instruments, the board may be either of black enamel slate or of black, dull-finish slate.

### SIZES OF PANELS.

It is the practice to furnish all switchboards, except in special cases, of a standard height, *i. e.*, 90 inches; the top section is 31 inches high, the middle section 31 inches, and the bottom section 28 inches. All panels have 3/8-inch bevel on their front edges. The standard widths of panels are as follows: 16, 20, 24, and 32 inches.

All switches are provided with card holders for labels designating the use of the different switches.

# The Military Resources of the United States of America

(Translated from "Beiheft" 94, "Internationale Revue uber die gesamten Armeen und Flotten," February, 1908, by Henry E. Haferkorn, Librarian, Engineer School.)

The military resources of the Union consist not only of a very responsible and efficient navy and numerous more or less well-constructed coast defences, but also of a Regular Army.

With reference to the present organization of the latter, and its military value, the following data may be of interest:

The law of 1901, relating to the organization of the military forces, gives to the President the right to annually fix the peace establishment within limits varying from 58,924 to 96,766 men. In conformity with this law, the Army, in round numbers, since the suppression of the Philippine revolt has been kept at about 60,000 men.

According to the report of General Ainsworth, Adjutant-General, dated July 31, 1907, and recently published, the Army, not including the Medical Corps, consisted of 3,797 officers and 59,827 men, only 2,625 officers and 33,860 men being stationed at home.

But, since the Government has finally consented to the organization of a General Staff Corps, whose duty it is to examine and direct all matters relating to the military land forces, a peace establishment fixed at 60,000, in round numbers, has not been deemed large enough to form the only nucleus of military National defence, and a considerable addition thereto, as well as an improved organization of the Army, has been urged, regard being had to the fact that of the present strength 804 officers and 17,242 men are stationed in the Philippines, 276 officers and 4,437 men in Cuba, 52 officers and 1,011 men in Alaska, 27 officers and 601 men in Porto Rico, and 12 officers and 209 men in Hawaii.

In accordance with these ideas, the Third Division of the General Staff prepared a scheme some time ago giving the Regular Army a strength of 60,000 men on a peace footing, and provided a newly organized reserve of regulars, numbering 50,000, which may be added to the Regular Army and which shall be at the immediate disposal of the President in case of war.

In addition to these, a National reserve of 100,00 men is urged. This reserve is to be composed of citizens who have not been in

the regular military service, but who have been drilled to a certain degree as volunteers in the militia or military colleges. Finally, an organized militia of 50,000 men is recommended with the specific understanding that these last two organizations, numbering 150,000 men, can only be mobilized for service in the field by an act of Congress.

Although the political sky is by no means free from clouds, Congress has not seen fit to decide upon the formation of a National reserve of 100,000 men. One reason for their failure to do so is the fact that it appears impossible to furnish the necessary number of officers for the regular reserve and for the National reserve at one and the same time. Another reason advanced is that, first of all, the more important and very expensive reorganization of the Artillery must be completed. This last reorganization has, however, as we shall see later, already been provided for during the year 1907, and it is now to be seen whether Congress will be considerate enough to act favorably on the recommendations of the War Department.

Having temporarily postponed the scheme of organizing a large army, the formation of a regular reserve of only 50,000 men, sanctioned by Congress during the spring of 1906, remains.

This regular reserve must be composed of such men, according to the wording of the act, as have been honorably discharged from the Regular Army, and who, during their military service, have been promoted to the grade of non-commissioned officer, or were sharpshooters, but who have not reached the age of forty. They are to be enlisted as reservists for a period of five years, and paid, according to their rank, twenty-four, twenty-eight, or thirty-two dollars per year.

They are required to bind themselves during their reserve service not to go beyond the borders of the United States, and be ready at any time when called upon to be mobilized by the War Department.

They must also agree to an annual training, or to a two weeks' drill every two years. Finally, they must report without fail in case of war to be used in the ranks of the Regular Army where reinforcements are needed.

From this reserve, and from the standing Army, are to be established depot battalions—that is, one for each Infantry, Cavalry, and Field Artillery regiment, one for the Engineers, one for the Signal Corps, and four for the Coast Artillery.

At first, these battalions, organized on the same lines as Infantry battalions, will consist of a staff of officers, non-commissioned officers, and 80 men. Their strength will be increased in time to 150 men.

The depot battalions will be officered by regulars—that is, by retired officers—and by persons who are eligible according to the law establishing the reserve.

The only disadvantage in this new and improved organization is the fact that it has not been possible to carry it out at once, and that it can only become an active factor after some years, when the necessary personnel shall have become available.

According to the scheme of organization these troops would be used merely as a reserve, which would have to be up to the necessary standard of fieldwork in the case of war, but which could not be used at once as a reinforcement for the field army of the first line. The militia will therefore remain, as before, the principal support of the Regular Army. This may be easily possible, for if one considers its strength according to the annual report of 1907, the militia under the fifty State and Territorial governments of the Union showed a strength of 9,154 officers and 110,347 men—figures which are not astonishing if it is considered that the law of January 21, 1903, makes all able-bodied American citizens between the ages of eighteen and forty-five subject to service in the militia and the reserve. No changes have been made in this provision in the new Dick bill of March 31, 1907. The only great drawback to the system is the fact that the training of the militia is still very defective, and that, according to the Constitution of the United States, even the President has no right to issue orders to the militia in time of peace. The President of the Republic in time of peace is the commander of the Regular Army only, while the militia is simply under the immediate orders of their respective State or Territorial governors.

Conditions are changed only in case of war, when the Commander-in-Chief takes command of the militia troops which are at the disposal of each governor, but there is nevertheless no obligation on the States or Territories to obey the President's call for such troops.

Important disadvantages of such an organization made themselves felt during the Spanish-American war, but not sharply enough, on account of the inferiority of the enemy, to bring about fundamental reforms. Only recently, however, these reforms have

again been urged as an absolute necessity in the interest of the National land defence by President Roosevelt in his message to Congress. This document treats particularly of the schemes to perfect the militia. In it reference is made to the excellent organization of the volunteer rifle clubs in Switzerland. These reform propositions embrace also a scheme for a thorough and systematic peace training of the militia.

The lessons learned during the combined training of the Regular Army and operations of the militia are to be applied in future by all the various arms. This will require practice maneuvers (resulting from the mutual efforts of the Secretary of War, William H. Taft, and the Chief of the General Staff, General Chaffee), consisting of an assembly of all troops for a period of several months on large maneuver grounds (seven in all) and in the establishment, during peace, of so-called "Brigade Posts," thus eliminating all small posts.

The preceding statements show that for the present, at least, the militia organization, and the newly created regular reserve established by the law of 1906, are not of very great military value and can not be considered seriously for service in the first line in case of war, excepting, perhaps, such organizations as are supervised and trained by particularly energetic governors and high officials.

The National land defence is, therefore, in case of hostilities, solely dependent on the regular standing Army.

The regular standing Army is organized, according to recent changes provided by Congress, into 30 Infantry regiments, each consisting of 3 battalions, each battalion of 4 companies; 15 Cavalry regiments of 4 (*sic*) troops each; 6 Field Artillery regiments, of which the First, Third, and Fifth are field batteries, and the Sixth a horse battery, each of 2 battalions, each battalion of 3 batteries, each battery of 4 pieces; 14 battalions of 170 batteries of Coast Artillery; 3 Engineer battalions, each of 4 companies, and Signal Corps with a balloon section.

Organization of the Artillery arm of the service is entirely new. Its principal new feature is the separation of the Field and Coast Artillery. This separation has been planned for several years, but has been postponed several times. Additional innovations are the restoration of the regimental system to the Field Artillery, and its organization into field, mountain, and horse batteries, as well as the increase of the Coast Artillery by 44 batteries. The

reorganization of the Field Artillery, and particularly its assembly at large posts, which was only decided upon last year, can not, however, be carried out as easily and uninterruptedly as the leading military spirits desire, in view of the importance and the necessary training of the arm.

One of the greatest difficulties incurred in assembling each of the newly formed regiments at one post is the want of barracks. In addition, colonial service and the occupation of Cuba still make separate commands necessary. As a result, up to the present, of the six regiments of field batteries not more than three are more or less partially assembled in one garrison. Only the Sixth Regiment of Field Artillery, composed entirely of horse batteries, has its six batteries completely assembled at Fort Riley. The Second Regiment of Field Artillery has only two batteries assembled at regimental headquarters; the other four batteries of the regiment are distributed at various points extending from Canada to Cuba.

The General Staff urgently recommends an increase in the Field Artillery, and declares that it is impossible to get along with the present force. Should Congress approve these recommendations, two additional stations along the Atlantic Coast would have to be manned—a separation, as already mentioned, which is greatly to be regretted so far as success in the training of the arm is concerned, but which, nevertheless, for practical reasons can not be avoided.

The General Staff has found it to be very inexpedient in preparing plans for mobilization of troops to station the entire Field Artillery at points which are very distant from the Atlantic Coast, where it would most likely not be needed, and where climatic conditions would be entirely different. The territory of the United States is immensely large and embraces regions of the most varying climatic conditions. For instance, horses which have been kept continuously in the same district for a number of years require a long time to get acclimated in other districts which are located possibly from 1,500 to 2,000 kilometers north or south.

This fact was again proved during the past year, when a number of horses which had been with northern regiments for a long time were used during the maneuvers in southern Texas. Differences of elevation are also of great importance and must not be neglected. Horses can not be brought from regions 1,400 feet above the sea to others located immediately on the ocean without suffering a certain amount of loss in the move.

The above facts, therefore, show very plainly that the practical distribution of the relatively small number of Field Artillery regiments on the extensive territory of the Union is by no means an easy problem and that its solution requires serious consideration.

In addition to the above problems, the General Staff is, furthermore, engaged on the question of doing away with all baggage and teams for the mountain artillery.

According to one authority, each battery is to have twenty pack mules for forage, clothing, etc., and according to another, each battalion of three batteries is to receive sixty-five pack mules for their train.

At present, experiments are being made in moving all tools, field forges, and other material on pack mules.

The small arm of the American army consists of the Springfield-Mauser rifle, model of 1903, caliber 7.62 mm. for both Infantry and Cavalry.

As in all other armies, experiments are being made in America with a new cartridge; it is a conical bullet,model 1906,and requires a slight modification in the barrel of the rifle and of the sight. Its merits are said to consist in a decrease in air resistance, avoidance of deviation of the projectile, and a flatter trajectory. Preparations are also being made to equip the Cavalry with the automatic "Marc" pistol of the Gabbet Fairfax type, in two calibers of 9 and 11.4 mm., respectively, in place of the Colt revolver.

The Field Artillery is equipped with recoil guns, model 1902, of 7.6 cm. caliber, which are supplied with shield. It is not, however, positively known whether or not all of the batteries have been equipped with this gun. Experiments are also being made with recoil howitzers, both heavy (15.2 cm.) and the light (12 cm. and 9.65 cm.). It seems, however, that a final decision on the question of howitzers has not yet been arrived at. A 12-cm. gun for the siege artillery has been tested. This gun has proved satisfactory, and two batteries have been equipped with it.

Of the greatest importance to the American Army is the General Staff, and the Staff College, which is combined with it. The Staff College is located at Fort Leavenworth, Kansas. It has not been in existence very long; in fact, only since the reorganization of the General Staff in 1903. It has, however, gained a very strong foothold lately and has developed wonderfully well.

The General Staff of the American Army departs in its system

and in its field of labor in many points from similar institutions in European armies.

The General Staff was established through the need of discontinuing the position of Commander-in-Chief on the retirement of General Miles, in 1903, and through the proposed separation of the chief command in peace and war.

In time of war, the chief command is to be given to the ranking general with the title of "lieutenant-general." In time of peace, however, the newly appointed Chief of the General Staff is to have supervision of the Army. He has as his immediate superior the President of the Republic; he can, however, by direction of the latter, be placed under the orders of the Secretary of War.

The Chief of the General Staff has also under his jurisdiction the departments of the Adjutant-General, the Inspector-General, the Judge-Advocate-General, the Quartermaster-General, the Subsistence, Medical, and Accounting Departments, the arsenals, and, finally, the Engineer and Signal corps.

The General Staff is charged with the consideration of all strategic questions and the preparation of plans for the mobilization of the Army. Furthermore, they study foreign organizations, organize the transport service, etc.

With the above purpose and duties in view the General Staff Corps has been created. Its personnel consists of two generals, four colonels, six lieutenant-colonels, twelve majors, and twenty captains and lieutenants.

After four years of service with the General Staff, each officer is required to serve with troops for a period of two years, after which he is again eligible for detail with the General Staff.

The Chief of the General Staff occupies a most responsible position and requires not only great familiarity with all military matters, in order to successfully administer his office, but also needs an unusual amount of tact. The reason for this is evident. Under former conditions only the Secretary of War and the Commander-in-Chief had to be reckoned with, whereas there are now three, or, in reality, four commanders of the Army, each one of whom has a right to be heard in military matters. These commanders are the Secretary of War, the Lieutenant-General, and the Chief of Artillery, who is also a general, and who is the only officer who serves as an ex-officio member of the General Staff.*

*On account of the reorganization of the Artillery, already mentioned, and the separation of the Field and Coast Artillery, the Chief of Artillery ceased to be the commander of the former arm.

Beginning with January 7, 1908, there will be only a Chief of Coast Artillery, with the rank of general, who will be an ex-officio member of the General Staff.

But, as we have already pointed out, the General Staff has developed splendidly in spite of the numerous difficulties placed in its way.

In no small degree the Staff College at Fort Leavenworth has been a valuable aid to the General Staff, and, in consideration of this valuable assistance, new and carefully prepared regulations covering the work and organization of this school have been issued by the War Department.

According to these regulations the aim and purpose of the college are to apply practically the experience gained elsewhere, but not to aim at an academic education.

The aim of the college is also to manage and supervise military education not only in the Army, but also in civil institutions to which, in accordance with an act of Congress, officers of the Regullar Army may be assigned as instructors. Finally, an opportunity to secure military education is offered militia officers through this school.

The personnel is detailed partly for permanent and partly for temporary service. It consists of the director, appointed by the Secretary of War, of officers detailed from the General Staff, and of officers of the rank of captain who have been recommended by the War Department as suitable instructors, assigned for temporary duty.

The course commences on November 1st of each year and lasts only twelve months. No examinations are required, but officers may be returned to their commands if it is found that they are neglecting their duties.

The Staff College is therefore to be really considered as a preparatory school of the General Staff. No promotion, however, results from attendance at the college.

What the result would be if the United States became involved in a war with an adversary whose army was organized and trained according to modern practice is, of course, conjectural. But it is an indisputable fact that the drill regulations, in accordance with which the forces in the United States are now being trained, do not entirely come up to modern standards. The infantry drill regulations, particularly, are based on obsolete methods, and similar conditions exist in other arms. The Field Artillery alone have recently received new provisional drill regulations. These are based on the French regulations, and following the latter the battery

organization is fixed at four guns and twelve caissons; six of the latter are assigned to the fighting battery.

An unlimbered caisson is placed to the left of each piece when in action. The limbers of the fifth and sixth caissons are each placed at a flank of the battery. Each piece is served, as in the French system, by six men, of which two ride on the limber, two on the carriage, and two on the caisson.

The method of firing is very similar to that of the French. Firing under cover is considered as being of the greatest importance.

All possible means are employed to deceive the enemy—such as construction of blinded embrasures, use of dummy guns, etc.

The separate groups and batteries are to be deployed, and crowding of Artillery is to be avoided in order that combined firing may be continued with certainty, and that the whole firing line may be covered as far as practicable.

The regulations for the service of security and information are very detailed. Each battery and section is provided with a separate personnel and with apparatus for gaining information and transmitting messages.

The use of the telephone is controlled by special regulations; non-commissioned officers are specially detailed as telephone operators, while others are assigned to reconnaissance duties.

In conclusion, we can only speak in the highest terms of the excellent personnel of the American Army, and in addition we must admit that the equipment of the American troops is very good.

In addition to this, the training of junior officers in cadet schools and in the reorganized military colleges is steadily approaching a perfection which will finally result in an efficient National defence.

# MEMORANDUM ON DREDGING WORK IN AMBROSE CHANNEL

*BY*

CAPT. H. L. WIGMORE
*Corps of Engineers, U. S. A.*

Up to and including the year of 1899 the only thoroughfare for deep-water navigation of the Port of New York was by way of Main Ship and Gedney channels. The project under which these channels were then being dredged provided for a width of 1,000 feet, 30 feet deep, extending over 11 miles in length.

The River and Harbor Act of 1899 adopted a project for making an entrance to New York by way of Ambrose Channel, formerly known as East Channel.

This project provided that the new channel, 7 miles long, should be 2,000 feet wide and carry a mean low-water depth of 40 feet. The excavation required was estimated at 42,500,000 cubic yards, and the act limited the cost of this work to $4,000,000. It was originally intended that the entire work would be performed by contract, and a bid of 9 cents per cubic yard was accordingly accepted. Progress was so slow, however, under the contract, that in 1903 two dredges were built by the United States to supplement the contract work. In October, 1906, the contractor abandoned work entirely, and since then it has been carried on by the United States alone. The River and Harbor Act of 1907 increased the limit of cost of the work to $5,148,514, and, under authority of this act, two more dredges were constructed.

In September, 1907, the new channel was opened for day navigation to ships of 600 feet in length and 29 feet or over in draft.

At the present time a width of 1,000 feet, carrying 40 feet of water the entire length of the channel, is practically completed, 35,000,000 cubic yards of material having been removed to bring the project to this stage.

It has been found that, due to over depth in dredging, which averages 2½ feet, the original estimate should be increased by about 7,000,000 cubic yards, independent of the filling that may be going on.

The plant now in operation consists of four sea-going suction dredges, viz: The "Manhattan," in operation since November 15, 1904; "Atlantic," since April 28, 1905, and the "Raritan" and "Navesink," in full operation since July 1, 1908.

The "Manhattan" and "Atlantic" are boats of 2,670 tons, 288 feet long and 47½-foot beam, with a draft, light, of 10.5 feet and loaded of 22 feet.

The "Raritan" and "Navesink" are 2,930 tons, gross; 290 feet long, 47½-foot beam, with a draft, light, of 14.3 feet, and loaded 24 feet. They were built by the Maryland Steel Company.

Both old and new boats are much alike, with the exception of a few improvements in details, incorporated in the plans of the newer boats. For more exact information as to these improvements, see page 1030, volume 2, of the Chief of Engineer's Report of 1907.

Their general appearance is that of the usual steel-hull freighters, except for the suction tubes, which project from each side about one-third the length from the stern. Inside, however, they consist principally of two large bins, of steel boiler plate, extending in depth from the upper deck to the bottom of the ship, and each in length about one-sixth of the ship's length. The forward bin occupies the after part of the forward third of the ship and the after bin the forward part of the after third.

The lower 5 feet is divided into eight inverted truncated pyramidal sections, each fitted at the bottom with a horizontal gate in each section, swinging on horizontal fore and aft hinges.

These gates are 3 feet 6 inches by 4 feet 4 inches, and while not absolutely water-tight are practically so. They are opened by vertical wrought-iron rods carried up to I-beams running across the top of the bins and operated by power through a worm-and-toothed gear or by large hand wheels. About 3 feet from the gate the rod has an eye-bolt splice, which permits the rods to maintain their verticality while the gates are swinging. The bins are built in the ship quite independently from the hull and are heavily braced along the sides and bottom by I-beam struts extending from the exterior of the bin to the hull. Stiffening pieces were also placed across the ends in the newer boats, but these are believed to be quite unnecessary.

Fore and aft tie rods connect the two ends of each bin in the older boats, but these have been found to be not only unnecessary but a positive evil, as the constant fall of mud tends to bend them

and so pull them out of their fastenings or buckle the end plates of the bins.

The forward bins in the old boats have a capacity of 1,270 cubic yards and the after bins 1,200 cubic yards. Their usual load is, however, only about 2,000 cubic yards. In the new boats the forward bins have a capacity of 1,527 cubic yards and the after bins 1,391 cubic yards. In good weather they usually carry about 2,700 cubic yards, reducing to 2,500 in a rough sea.

The vessels are all twin screw with an ordinary speed of 10 knots. Their engines are compound, each of 850 horsepower, but can produce about 930.

The pumping and dredging apparatus is, of course, the principal feature of these boats. This consists of two centrifugal pumps, 8½ feet in diameter, placed in the engine-room compartment, midway between the main deck and the floor of the engine room, on each side of the ship. These pumps are operated independently, each by a compound marine engine of 465 horsepower and making 155 revolutions per minute. In the old boats, where the pump vanes are worn, as high as 205 revolutions are made. The consumption of coal for all purposes is about 40 tons per day of twenty-four hours.

One condenser in the new boats serves all engines, while the old ones have one condenser for the propeller engines and one for the pump engines. Each pump is direct connected by a shaft to its own engine, and from its exterior the suction pipe leads through the hull to the outside of the ship, where an elbow attached by a movable joint permits the rest of the suction pipe, extended aft longitudinally along the hull of the ship, to have a vertical motion. Below this elbow is a ball-and-socket joint, which gives play to this same part when in operation. At the end of the suction pipe is what is known as a drag, which is an improved and far more efficient form of the old bell-shaped mouthpiece. It is in general appearances a flattened extension of the suction pipe with the lower half cut off and a heavy iron grating having about 8-inch openings substituted therefor. The suction pipes are raised and lowered by wire falls hung from special davits located on the upper deck over the end of the suction pipes. The falls are operated by two horizontal engines with 8-inch by 10-inch cylinders, connected to the drums. The engines are controlled through levers from a small bridge by the davits. The pumps are of the usual vane type of centrifugal pump with some changes found to give greater

durability. These consist of the substitution of steel castings in the shell for cast-iron, as it was found that cast-iron could not withstand the impact of stones brought up through the pipes.

Steel lining for the vanes was also found impractical, as the first notice of wear there was generally a piece of the lining coming out through the shell.

In the new vessels there are five vanes in each pump, as compared with four in the older type. The material is received at the axis and is then carried by the vanes around to the receiving tube, which leads upward at an angle of 90 degrees and branches 2 feet from the fan. One branch leads to the forward bin and one to the after. Overflow pipes permit the water to run off till the bins are filled with solid material.

All pipes are interchangeable and are 20 inches in diameter. Where the branches reach the top and end of the bins, they open through a wooden gate fitted with rubber gaskets into rectangular sluices made of heavy wrought-iron plates, from which the dredged material is allowed to fall into the bin from any or all of these openings. Either branch can be cut off so that all the material can be delivered into one bin. With different materials, of course, the capacity of the pumps varies slightly. The average capacity of the new pumps, at about 35 feet depth and dredging fine, hard-packed sand, is 13 cubic yards per minute or 6½ cubic yards per pump, running at 155 revolutions.

In loose sand and fine gravel the average is about 20 cubic yards per minute; in soft mud, about 9 cubic yards. This, it should be noted, is solid material as carried to the dumps, not the actual capacity of the pumps, which averages 172 cubic yards of liquid matter per minute or 86 cubic yards per pump.

In operation, the average time for filling the bins may be taken as three hours and ten minutes. From the operating ground to the dumping ground and back will generally, on the average, considering work over the full length of the channel, take two hours and thirty minutes, which includes ten minutes for dumping. About five minutes is lost each time the dredge has to turn while at work.

## COSTS.

In calculations of the cost of operation of these dredges, only those items that would be considered in a contractor's figures should be used; as the item for consideration is, whether the work could be done cheaper by contract. Therefore, cost of surveys

and examinations should not be considered, but, conversely, interest, insurance, and sinking fund should be.

In estimating the cost of the completed work to the Government, all the above, however, except interest and insurance, should be included.

The record of the operation of the "Manhattan" and "Atlantic" for the complete year ending June, 1908, being on file, the following is shown for the operation of the "Manhattan:"

| 1907-8. | †Pay roll. | Coal. | Subsistence. | Supplies. | General repairs | Wharfage. | Totals. |
|---|---|---|---|---|---|---|---|
| July | $2,994.33 | $2,743.30 | $729.18 | $175.95 | $3,725.33 | $62.50 | $10,430.59 |
| August | 2,846.83 | 3,335.06 | 879.29 | 458.05 | ..... | 62.50 | 7,581.73 |
| September | 2,836.58 | 2,449.75 | 841.57 | 220.26 | 262.87 | 62.50 | 6,673.53 |
| October | 2,877.66 | 2,468.38 | 838.38 | 164.05 | 344.88 | ..... | 6,693.35 |
| November | 2,919.67 | 3,048.40 | 931.92 | 673.58 | 895.07 | 125.00 | 8,593.64 |
| December | 3,015.25 | 2,536.85 | 731.31 | 450.86 | 69.84 | ..... | 6,804.11 |
| January | 2,898.83 | 2,434.54 | 811.04 | 242.57 | ..... | ..... | 6,386.98 |
| February | 2,806.33 | 3,464.53 | 919.65 | 594.56 | 235.23 | 187.50 | 8,207.80 |
| March | 2,862.16 | 2,692.04 | 780.73 | 622.22 | 9.89 | 62.50 | 7,029.54 |
| April | 2,898.50 | 2,510.82 | 758.57 | 446.54 | 864.74 | 62.50 | 7,541.67 |
| May | 3,129.66 | 2,317.48 | 967.16 | 363.90 | 710.78 | 62.50 | 7,551.43 |
| | | 2,794.44 | | | | | |
| June | 2,705.83 | 2,024.47 | 801.71 | 292.30 | 119.18 | 90.00 | 8,827.93 |
| Total | $34,791.63 | $34,820.06 | $9,990.46 | $4,704.84 | $7,237.81 | $777.50 | $92,322.30 |
| | *2,400.00 | ..... | *2,400.00 | ..... | *a*13,131.80 | ..... | *a*13,131.80 |
| Total | $32,391.63 | $34,820.06 | $12,390.46 | $4,704.84 | $20,369.61 | $777.50 | $105,454.10 |
| | *b*1,500.00 | ..... | ..... | ..... | ..... | ..... | *b*1,500.00 |
| Total | $31,891.63 | $34,820.06 | $12,390.46 | $4,704.84 | $20,369.61 | $777.50 | $103,954.10 |

†Pay roll. The full complement of the "Manhattan" is 58 men, exclusive of the inspector.
*Cooks and waiters transferred to subsistence.
*a* For repairs and supply of worn and broken parts, yearly account.
*b* Inspector's salary would be paid by United States on contractor's plant.

| | | |
|---|---|---|
| The total yardage of the "Manhattan" for the period June 30, 1907, to June 30, 1908, was 2,660,513 yards. Taking the total cost of operation as $103,954.10, which includes all items of expense which would be borne by a contractor, we have a cost per yard of | | $0.039 |
| Building cost of "Manhattan" was | $340,041.58 | |
| Ten per cent sinking fund | 34,004.16 | |
| =per yard | | .0127 |
| Insurance and interest taken at 7 per cent | 20,802.91 | |
| =per yard | | .0078 |
| Cost to a contractor | | $0.0595 |
| There should be an allowance of 12½ per cent in this case for over depth in dredging for which the contractor is not paid=per yard | | .00557 |
| Total | | $0.06507 |
| Total cost to the United States was as follows (excepting cost of vessel): | | |
| For cost surveys and examinations for two boats $19,983.34 or $9,991.67, chargeable to the "Manhattan"—per cubic yard | | .0037 |
| For office and conting't expenses $6,752.15,$3,376.075 for the "Manhattan." To this should be added $1,500 for the inspector's salary—per cubic yard | | .00183 |
| Operating as before—per cubic yard | | .039 |
| Sinking fund as before—per cubic yard | | .0127 |
| Total cost to the United States | | $0.05723 |

The "Manhattan" and "Atlantic," now three years in operation are, so far as condition is concerned, as good as when new. Their efficiency is much greater than when first placed in operation.

In the case of the "Raritan" the records for the first three months of her operation show a total cost of operation of $22,285.46. She removed in this time 641,513 cubic yards, giving a cost per yard of 3.58 cents.

The other items for arriving at the total cost to United States, not at present obtainable, would be approximately the same as for the "Manhattan," making the total cost to the United States of $0.05403 per cubic yard.

The work has been in charge of Gen. W. L. Marshall up to now, assisted by Lt. Col. S. W. Roessler, H. N. Babcock, Assistant Engineer, and H. L. Potter, Junior Engineer.

# NOTES ON DEMOLITIONS

*BY*

CAPT. LYTLE BROWN
*Corps of Engineers, U. S. A.*

PINE CAMP, JEFFERSON COUNTY, N. Y.,
*July 8, 1908.*

*Problem No. 1.*—Ninety-five pound rail with one-half pound 40 per cent dynamite, without tamping, against the web on top cross tie. *Result:* Blew out 12 inches of rail.

*Problem No. 2.*—Same rail with one-half pound 40 per cent dynamite, under bottom flange of rail between cross ties, without tamping. *Result:* Loosened nails in two cross ties, and broke out 6 inches of bottom flange; very slight damage to rail.

*Problem No. 3.*—Same rail with one-half pound 40 per cent dynamite between cross ties, under bottom flange, with two sand bags, one on each side, earth tamped around same. *Result:* Broke rail clean, blew out 16 inches of bottom flange, loosened nails in about seven cross ties; also raised several cross ties, and bent the rail at fish plate.

*Problem No. 4.*—Same rail, one-half pound 40 per cent dynamite, laid on loose cross ties placed under joint of rails, and earth well tamped, with two sand bags, one placed on each side of rail. *Result:* Broke three fish-plate bolts, spread cross ties and loosened nails in eight cross ties.

*Problem No. 5.*—Same rail with three one-half pound 40 per cent dynamite sticks placed against web of rail over alternate cross ties, with one sand bag against each charge. The three charges were fired at one time with exploder. *Result:* Broke out 9 feet of rail clean, tore up five cross ties.

*Problem No. 6.*—Same rail with two one-half pound 40 per cent dynamite sticks, at a suspended joint, one stick placed over each cross tie, against fish plates of rail, also one sand bag over each charge. The two charges were fired at one time with exploder. *Result:* Broke out bottom flange of each rail for 12 inches and bent two rails slightly (about 2 inches); also loosened nails in six ties and moved track about 1 inch.

*Problem No. 7.*—Same rail with three one-half pound 40 per

cent sticks, each placed over a cross tie with two ties between, against web of rail, with a sand bag over them. *All* fired at same time by exploder. *Result:* Broke out 15 feet of rail clean; at each charge a piece of rail was blown away.

*Problem No. 8.*—One one-half pound stick 40 per cent dynamite placed over a cross tie, against web of rail, with fuse and cap, and another placed five cross ties away (10 feet) against web of rail, without fuse or cap, each with sand bag covering. *Result:* Did not fire the charge without fuse or cap; tried again with interval of 4 feet (two ties), same result.

*Problem No. 9.*—Two one-half pound sticks placed against web of rail on cross tie with 5-foot piece of rail and a sand bag over charge. *Result:* Broke out 2½ feet of rail clean.

*Problem No. 10.*—Three one-half pound sticks, one placed under suspended joint of rails with two sand bags, two placed two cross ties away on each side of joints on opposite side of rails. *Result:* Broke out 10 feet of rail clean, and slewed opposite joint out about 3 inches; also loosening nails on opposite side of rail.

*Problem No. 11.*—Two one-half pound sticks tied around 12-inch tree and sand bag hung on nail covering them. *Result:* Split tree on three sides for about 5 feet.

*Problem No. 12.*—Three one-half pound sticks placed in sand bag hung on nail on 12-inch tree. *Result:* No damage, except to vibrate the tree a little.

*Problem No. 13.*—Two sticks, one placed on top of rail and one under bottom of rail, about 2 feet apart. *Result:* No damage.

*Problem No. 14.*—Four sticks, at suspended joint, two on each side of rails over cross ties, against fish plates, with a sand bag over each, one with fuse and cap, the other without. *Result:* Broke bottom flange off rail having charge with fuse and cap; the other charge was not exploded nor the rail damaged.

*Problem No. 15.*—Same as Problem No. 14, except both charges contained fuses and caps and the earth well tamped under joint. *Result:* Cracked each rail and bent them; also broke pieces of bottom flange and part of fish plates; loosened and broke all the bolts.

# The Work of the Department of Electrical and Mechanical Engineering*

*BY*

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*Instructor, Electrical and Mechanical Engineering*
*Engineer School*

It is thought well to enumerate briefly at this time some of the essential features pertaining to the course of instruction in this department. It is evident that you have passed that stage in your education where you wish to study merely for the grade or marks that you obtain from an instructor, and it is time, therefore, that practical knowledge, coordinating the theoretical and the practical sides of these branches of engineering, should be procured.

The work of the department will be carried on along four lines: First, the theoretical, or that which pertains to the reading of works by standard authors of engineering; second, laboratory practice, incorporating the operation of machines and apparatus on test and the compiling and interpretation of the data taken in the laboratory; third, illustrated lectures by the instructor and others, the object being to coordinate both the work of the laboratory and reading courses; fourth, the solution of practical engineering problems, the data of which have been picked up by the instructors in their experience or from data on power plants and systems of this country.

(1) *Reading Course.*—The theoretical work which pertains to the reading of references is not satisfactory to the writer. There is such an accumulation of theory, data, and both poor and good practice incorporated in the publications on the subject that it is hard to cover it thoroughly without reading and re-reading a good deal of unnecessary matter. You will further note that the profession is so rapidly changing that it is impracticable to outline a given course of instruction for any one particular year and use it for succeeding years. The development along these lines is so recent and varied that it is next to impossible to coordinate the matter satisfactorily, accurately and economically as to time. You will therefore have to content yourselves with reading a good deal of matter a number of times in order to get the viewpoints of va-

*Being extracts from the instructions and outline issued to the Student Class at the Engineer School, November 30, 1908.

rious engineers. The aim is to make the reading as short as possible, covering the greatest amount of matter in the time available, but it is deemed unnecessary to commit to memory the material read, or, in other words, to carry on that process of learning which is known as "specking."

In this connection I will state that there are to be no examinations held in this department. There will be no marking or grading of each man's work other than to see that it is satisfactory. Of course, the most practical part is the laboratory work; both the aptitude and ideas shown in the laboratory by each individual, and the originality displayed in working up and showing practically the results of the tests, being highly considered. We must remember that we are studying engineering for what we can get out of it, and not studying to graduate from the Engineer School. I venture to say that if this idea is kept in mind the maximum efficiency will be obtained.

(2) *Laboratory Work.*—The writer has compiled a set of laboratory notes and instructions which covers, incompletely, the work that we intend to carry on in this department. The tentative outline is as follows:

ELECTRICAL ENGINEERING LABORATORY.

*Twelve Weeks—Twelve Laboratory Hours Per Week.*

1. Measurement of Resistances.
2. Starting Direct-Current Motors.
3. Adjustment of Brushes of Generators and Motors.
4. Calibration of Ammeters and Voltmeters by Comparison with Standards.
5. Potentiometer Measurements of Electromotive Force and Current.
6. Calibration of a Weston Indicating Wattmeter.
7. Direct-Current Motor Speed Characteristics.
8. Direct-Current Generator Characteristics.
9. Direct-Current Motor Efficiency Tests.
10. Direct-Current Generator Efficiency Tests.
11. Efficiency of a Direct-Current Generator by the Opposition Method.
12. Acceptance Test of a Direct-Current Generator.
13. Single-phase Alternator Characteristics.
14. Efficiency Tests of a Polyphase Alternator.
15. Transformer Testing.
16. Transformer Connections.
17. Polyphase Induction-Motor Tests.
18. Motor-Generator Testing.
19. Paralleling Direct-Current Generators.
20. Synchronizing Alternating-Current Machines.
21. Tests of a Polyphase Rotary Converter.
22. Acceptance Test of an Alternator.
23. Storage Battery Testing.
24. Photometry of Incandescent Lamps.
25. Constant Potential Arc Lamps.
26. Series Alternating-Current Arc Lamp System.
27. Testing Recording Wattmeters.

28. The Mercury Vapor Arc Lamp.
29. The Mercury Arc Rectifier.
30. Signal Corps Telephones.
31. Signal Corps Telautograph System.
32. Searchlight Operation.
33. Oscillograph Operation.

MECHANICAL ENGINEERING LABORATORY.

*Six Weeks—Twelve Laboratory Hours Per Week.*

1. Calibration of Steam and Vacuum Gauges.
2. Determination of the Amount of Moisture in Steam.
3. Tests of a Live Steam Separator.
4. Calibration of Water Meters.
5. Operation and Test of Injectors and Inspirators.
6. Tests of a Boiler Feed Pump.
7. Tests of an Open Feed Water Heater.
8. Determination of the Heating Value of Coal.
9. Steam Boiler Testing (A. S. M. E., Code of 1899).
10. Study of the Steam Engine Indicator and Indicator Cards.
11. Calibration of Indicator Springs.
12. Steam Engine Valve Setting.
13. Test of a Simple, High Speed, Condensing Engine.
14. Test of a Hornsby-Akroyd Oil Engine.
15. Test of a Four-Cycle Gas Engine (City Gas).
16. Test of a Four-Cycle Gasoline Engine.
17. Test of a Four-Cycle Alcohol Engine.
18. Acceptance Test of a High-Speed, Gasoline Engine Driven Generating Set.

The laboratory notes are divided into the following headings: "Subject," "Apparatus," "Theory," "Method," "Discussion" and "References."

Under the heading "Apparatus," I have enumerated, as far as possible, the particular instruments that are on hand to be used during that test. Due to accidents and other causes, we will find throughout the course that some of the instruments indicated are not applicable to the work, and when such cases arise the instructor in charge will designate the instruments to be used.

Under "Theory" there has been given, in most cases, the theory of the apparatus at hand, together with figures and diagrams which tend to explain the characteristics of the apparatus.

Under the heading "Methods," you will find diagrammatic sketches of the connections which are to be used in making the laboratory tests and general directions for running the tests. You will, no doubt, find it hard at first to coordinate the actual connections with those shown in the figures, but when you are able to connect up your machine in theory—by diagram—and then connect it up so that it will operate properly without developing a short circuit or other extraordinary operating characteristics, you have mastered the fundamental principle of practical electrical engineering.

We are furnishing, in the laboratory, general log sheets for recording the laboratory data. The original of each log sheet will be sent to the office of the department for note and file. The data taken in the laboratory will be corrected for instrumental errors, and this corrected data with computed data and results will be recorded on the record sheets furnished with each experiment.

Under "Discussion" there has been enumerated a set of questions about which one student officer made the remark that "The discussion was a continuous examination." These questions are not asked in that frame of mind, however, the sole object being to bring out the principal points suggested by the apparatus at hand, and which, when thoroughly answered, should undoubtedly clear up the necessary points about that particular apparatus. This must be individual work throughout.

Under the heading "References," there is given data on books which are in the office of the department and in which books information bearing on the questions asked under the discussion will be found. You will, no doubt, find in a number of cases that the references are not very explicit and not clear, because, as I have said above, we must look through a good deal of matter to find the point that we need.

The log sheets shall be made out in the laboratory by some student officer designated by the instructor, and carbon copies will be made, so that each officer will have a copy of the data obtained in the laboratory. He will, therefore, be entirely independent in compiling and computing his data for the record. It must not be misunderstood that each officer must, individually, compute his entire test, because it is believed that if each section work up the test together that they will obtain better results by checking each other's work than if the work was accomplished individually. Each student officer must, however, compile his own record of the laboratory test, plot his own curve sheets and write his own discussion.

Therefore, be sure and study thoroughly the experiment before coming to the laboratory. Be sure you know what you are going to do, and if possible look over the apparatus before the day of the test.

It has become a practice in engineering to show experimental data diagrammatically, thereby showing the general relation, or, rather, the average results of the test. For instance, we can not say that any particular set of readings at any instant are abso-

lutely correct, but we can say that if the experiment is carried over a wide range of operation a line drawn through the data points, for various conditions, plotted to scale, will indicate at a glance the average condition of operation shown by that machine in that particular test. This method of compiling test data will be carried out explicitly in these laboratories, because it is the engineering practice of the day. A curve sheet of a test showing the various relations between load, efficiency, iron losses, speed, etc., means more to us than a whole book of data taken at infinitesimal increments of load, etc.

You must, therefore, learn to plot curves in the form that will do the most practical good, and keep the following points in mind while plotting curve sheets:

1. Place as many curves for each test on one sheet as is practical.
2. Clearly designate the coordinates.
3. Name each curve on the sheet.
4. Clearly indicate each data point by a small circle, made preferably with a bow pen.
5. Show clearly the test which the sheet explains.
6. Give on the curve sheet the full rating of the apparatus tested.

It is desired that the above points be followed, because it is believed that the work will be more thoroughly understood and better results and engineering practice obtained.

I realize we are not all born draftsmen, but I thoroughly believe that one will get more substantial engineering information out of his work if he carefully compiles his test data into curve form. You, therefore, should take as much pains as time will permit in drawing and lettering your curve sheets.

### LABORATORY REPORTS.

The completed laboratory report must be submitted within one week from the day the work in the laboratory on that experiment shall have been satisfactorily completed. It will be corrected by one of the instructors and returned to the student officer within the week following, after which any corrections requested by the instructor shall be made and the report submitted for final correction and approval.

(3) *Lectures.*—It is hoped that these lectures will aid in knitting the divisions of the course more closely together. I am sorry

to state that it seems impossible to have the lantern slides made into cuts and the lectures printed. You will have to content yourselves with seeing the illustrations presented on the screen, and, as far as possible, remembering them when you re-read the typewritten copies of each lecture, which will be furnished each student officer.

The following lectures are scheduled:

GENERAL.

The Work of the Department of Electrical and Mechanical Engineering.

ELECTRICAL ENGINEERING.

1. Electrical Testing Instruments.
2. Electric Lamps and Lighting.
3. Direct-Current Machines.
4. Alternating-Current Generators.
5. Alternating-Current Transformers.
6. Alternating-Current Motors.
7. Rotary and Static Transforming Apparatus.
8. Switchboards and Their Design.
9. Electric Power Transmission.
10. Electric Cables and Conduits.

MECHANICAL ENGINEERING.

1. The Generation of Steam.
2. Boiler Room Auxiliaries.
3. Steam Prime Movers.
4. Engine Room Auxiliaries.
5. Internal Combustion Engines.
6. Gas Engines and Gas Producers.

POWER STATIONS.

1. Washington Filtration Pumping Plant.
2. Capital Traction Power Plant and Sub-station.
3. Benning Power Plant.
4. Union Station Power Plant.
5. Firth-Sterling Gas Producer Plant.
6. Municipal Building's Isolated Power Plant.

This outline of lectures will be carried out as far as possible and as thoroughly as time will permit, the intention being to give a two-hour lecture per week, all lectures being illustrated by lantern slides. The lectures on "Power Stations" will be given in the morning of the day that the entire class will visit the plants enumerated above. In each plant the chief engineer or one of his assistants will accompany us and give us sketches of his experience with the plant and system.

NON-RESIDENT LECTURES.

The following outline gives incompletely the schedule for non-

resident lectures to be given under the auspices of this department during the coming year:

1. "Transmission of Intelligence in the Army."—By Maj. Charles McK. Saltzman, United States Signal Corps.*
2. "Submarine Mine Development."—By Maj. R. P. Davis, Coast Artillery Corps.
3. "Gas Engineering with Special Reference to Costs."—By Prof. R. C. Carpenter, Head, Department of Experimental Engineering, Sibley College, Cornell University.
4. "The Details of Electrical Measuring Instruments."—By Mr. Caryl D. Haskins, Manager Lighting Department, General Electric Company.
5. "Improvements in Central Station Engineering."—By Mr. Charles W. Stone, Electrical Engineer, Lighting Department, General Electric Company.
6. "Hydro-electric Developments and High-Tension Transmission."—By Mr. Ralph D. Mershon, Consulting Engineer, New York City.*

(4) *Engineering Problems.*—It is thought well to present this year again a set of practical engineering problems on the work taken up at the different parts of the course; that is, problems illustrating the operating characteristics and, sometimes, design characteristics of different types of machinery and installations. The intention is to give practical problems from my own notes and from notes of others illustrating the design and operating characteristics of electrical and mechanical machines. You will no doubt find it hard sometimes to find the connecting links of these problems, but by careful consultation of the handbooks recommended for this course, we see no reason why they are insolvable.

LABORATORY DIVISIONS.

The class will be divided into two sections of equal numbers as far as possible. The laboratory will be in operation from 9 a. m. to 4 p. m. with one hour off for lunch when the tests do not require continuous operation. The first section (if we may call it that) will report to the laboratories Mondays and Thursdays of each week, and the second section on Tuesdays and Fridays of each week. Wednesday will be reserved for lectures and for other work. In regard to the number of hours spent per day in or on this work, we leave that entirely to your judgment and discretion. From previous experience here I have found that it is impossible to cover the work thoroughly unless every one will conscientiously put in all the time that he can on the work. You will realize that eighteen weeks' time, or thereabouts, devoted to the work covered by this department is an inadequate time in which to condense the subjects, and we are therefore leaving the time element entirely in your hands.

*Probably.

It is my opinion that this School should be run on a graduate basis, and if you officers are not interested in the work that we are carrying on for your professional betterment, I know of no way of increasing the interest.

Lieut. W. H. Rose, Corps of Engineers, will be in charge of the laboratories and will be in personal supervision at all times. You are at liberty to consult us at any time on anything pertaining to the work and we assure you that we will do all in our power to answer your questions and present the subject in a clear and concise manner. The more arguments, the greater the interest taken and deeper the study, both of which we are trying to obtain. Your unbiased criticism of methods, machinery, and results is always welcome.

# Editorial Note

With this number the Professional Memoirs, Engineer Bureau, U. S. Army, makes its first appearance. It is hoped that every person connected with that Bureau will regard it as his own, a publication of the Bureau, for the Bureau, and by the Bureau. It purposes to live, and grow, and be useful. How to do so is the one problem before it at present.

This magazine is intended to assist every engineer in the service, to enable him to learn the work and ideas of others and to present his own.

It is doubtful if there is any class of men to be found who so delight in *seeing things* as do engineers. We do not mean ghosts or goblins. We mean *real* things. Let an engineer find himself within striking distance of any kind of engineering work, and he rushes to the scene all eyes and ears and note-book. And rarely does he fail to glean some new idea from each such visit. One of the purposes of this publication is to describe for engineers who are prevented by distance from visiting the scene of important operations, such interesting features as they would note if they could make an inspection in person. This should be kept in mind by those connected with the various works of the Engineer Bureau, and it should be their pleasant duty to send to the Professional Memoirs accounts of those features which they would take pleasure and pride in pointing out to visitors.

Another purpose is to describe in detail the various engineering problems which are daily being solved around us. No one man can in a lifetime solve more than a few of the problems confronting us, but by availing ourselves of the solutions made by others who have perhaps been more favored by opportunity or inspiration, we may vastly increase our powers and efficiency.

Records of failures are at times of even greater value than successful solutions, especially when the reasons for the adoption of the methods used and the causes of failure are clearly described.

Our field embraces civil, military, mechanical and electrical engineering and allied sciences so far as they appertain to our own

work, and in the course of many centuries we hope to cover the important and essential points of this field.

In military engineering we purpose to keep our readers in touch with the latest developments both at home and abroad. Original papers and translations on any of the subjects connected therewith are especially invited.

Discussions of papers, in a strictly impersonal way, are desired. As time goes on, editorial discussions may be undertaken to a limited extent; but, meanwhile, written comments are earnestly requested from all.

Technical details, which have of late years been necessarily omitted from the Reports of the Chief of Engineers, have from time to time appeared in separate pamphlets. It is thought that if published in the Professional Memoirs they would be available to a greater number of our engineers, and, consequently, be more valuable. Even if forming a part of official reports, the portions recommended for publication might readily be duplicated by extra carbons and forwarded to us through the regular military channels. We should thus receive nothing whose publication might be thought by the War Department to be undesirable.

In this first number we present a foreign view of our military establishment, and a few papers on civil, military, and electrical engineering. We also print an extract from the instructions governing student officers at the Engineer School in their course on electrical and mechanical engineering, this by way of letting our friends know what the School is trying to teach. It is expected that future numbers will review other branches of the School.

Our success will depend upon the cooperation of all concerned, and we ask the hearty support of every military and civil engineer and other person connected with the work of the Engineer Bureau. Subscriptions and contributions of papers, discussions, and notes and comments are essential; and we ask these for the common good of all.

# PROFESSIONAL MEMOIRS

*ENGINEER BUREAU, UNITED STATES ARMY*

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NOTE: Authors alone are responsible for statements made and opinions expressed in their respective articles.

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WOLSEY:

"Might is not all.
Shrewd thinking now wins further than stout blows,
The old arms rust, but from the new forged steel
Come flashings bright with thought. I pray your Grace
Forget that here are colleges and clerks;
Only remember here be men who think,
And even as the brain is master of the hand,
The master of the Nation's task is here.
Here let us build, but not with stones alone;
Let's build with courage, faith, and enterprise,
With daring, and a challenge to the unknown,
And most with honesty. Let's build a house
Wherein by subtle spirit — alchemy
Men may transform the wise high thoughts of old
To new and golden deeds. Then shall we build
As I have dreamed we built"——

*Oxford Historical Pageant, 1907.*

# IMPROVEMENT OF INLAND RIVERS*

*BY*

MAJOR W. W. HARTS,
*Corps of Engineers*

Rivers, as regarded from the standpoint of the engineer engaged in their improvement for navigation, may be classed as tidal and nontidal streams, depending on whether or not they are materially affected by the oscillations of the tide in the sea.

Most of our inland rivers are nontidal, and the main principles followed in their improvement for navigation are more or less similar. Although a study of the methods adapted to one stream may not always indicate what should be used on another, it is believed that lessons may be learned that may be of material help in designing work.

In general, methods of improving nontidal streams may be classified under the following heads:

1. By reservoirs to impound the flow at high water and release it at low water;
2. By contraction of the channel, including regulation;
3. By canalization;
4. By lateral canals;
5. By dredging.

In examining these methods, comments on each may be of some interest, and they will be taken up in order.

The Tennessee River has examples of each sort of improvement except the first, and will be used, therefore, in illustrating the principles set forth.

In preparing a project for any river the broad principles must be first settled as to what depths are desirable, taking into consideration not only the present and prospective use, but also the allowable cost of the work. The public use of an improved river, with the resulting general benefit, is the only dividend the Government receives for its investment of money, so that the engineer should apply ordinary business methods to his work and should as-

*A lecture delivered at the Engineer School, United States Army, Washington Barracks, D. C., November 23, 1908.

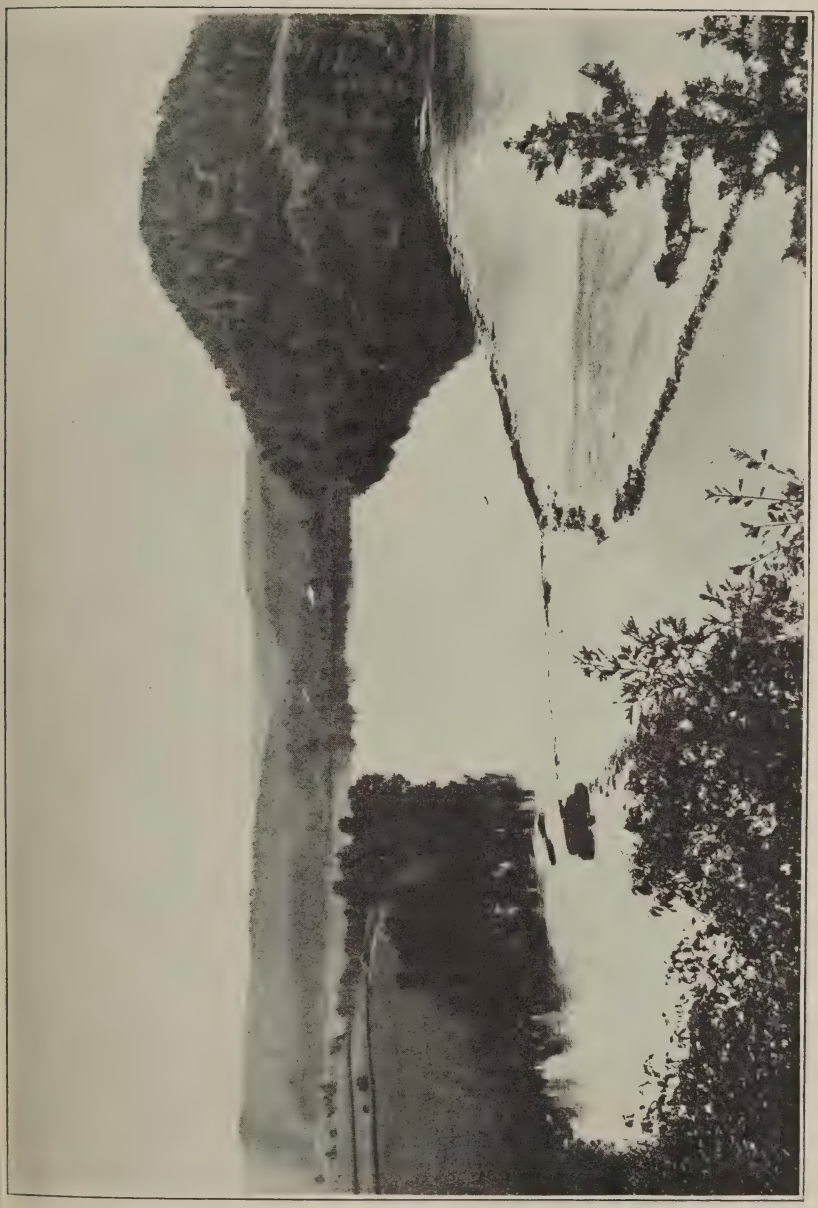
certain whether the investment will pay on some fair basis of computation. The limit of money properly applicable has been determined in some cases of improvement by capitalizing at some standard rate of interest the income that would be derived from an imaginary tonnage tax on the present and prospective commerce. Some such rule should always be applied as a test of the worthiness of the locality for Government improvement. Exactness is not to be expected, but such steps frequently serve as a useful guide.

### RESERVOIRS.

The method of using reservoirs in the head waters of streams for the sake of reducing floods, increasing the low-water flow, and improving the navigable capacity of the river, by storing water during times of excessive precipitation, has been persistently urged of late by its advocates, but is nothing new, as it was used more than two hundred years ago in Europe. Theoretically, this method appears to combine many desirable advantages.

The first use of this reservoir method of which we have any record is on the Loire, in France, early in the eighteenth century. The results were not satisfactory, so that when it was proposed to extend this system to the Garonne, to other portions of the Loire, and elsewhere in France, it was definitely decided against by the official action taken by the Bureau des Ponts et Chaussées, the official engineering organization of the French Republic. This investigation was a full and careful one, and resulted in the abandonment of the reservoir system for the prevention of floods in France, owing to the inefficacy of the method. Another example, this one for the improvement of navigable depths, is on the Volga and Msta, in Russia; two rivers flowing in different directions, whose head waters consist of a series of lakes forming in themselves large natural reservoirs, so that dams of light profile and of cheap construction were all that was needed to put this system in operation. Although the reservoirs have a capacity of 35,000 million cubic feet, the effect of the system in the direction of greater depths in these rivers was very limited.

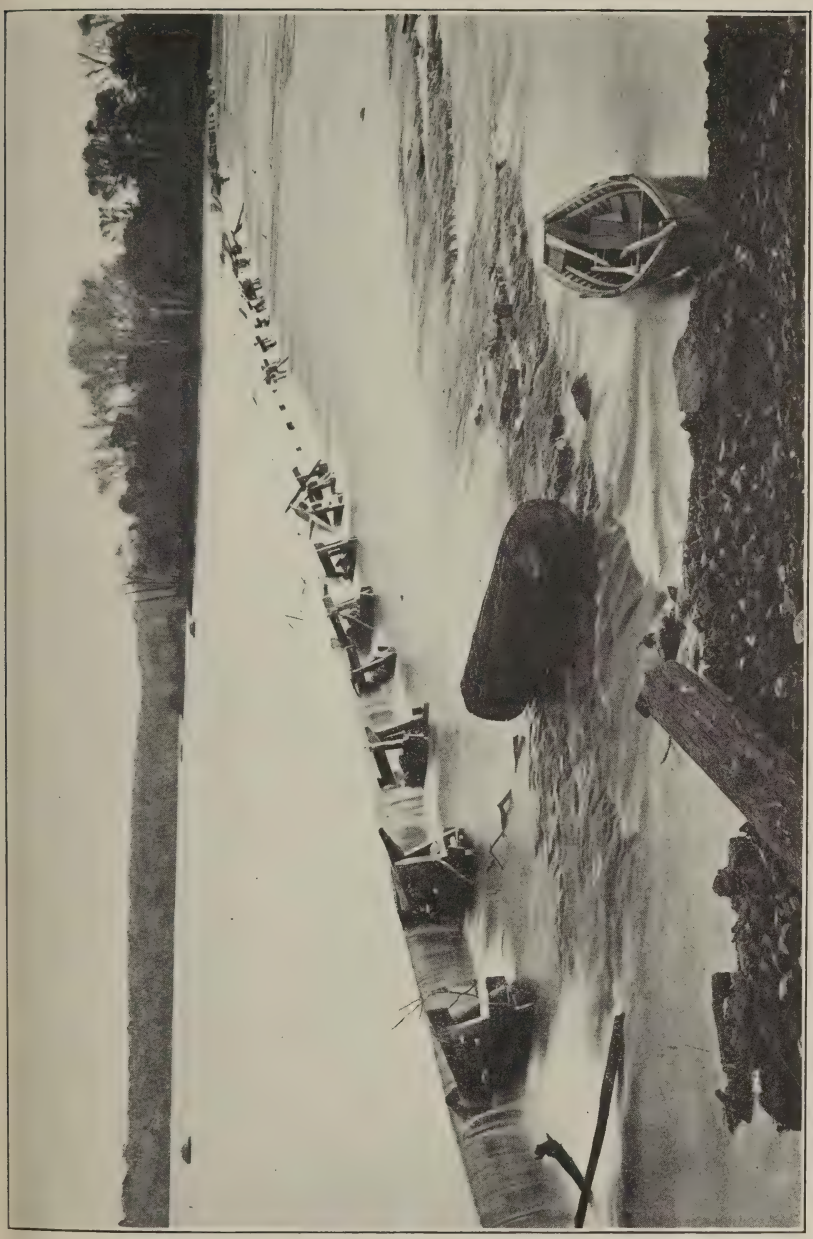
In our own country the plan has been tried on the Upper Mississippi (ostensibly for the improvement of navigation), where are located the greatest reservoirs for this purpose now existing in the world. In these reservoirs the storage capacity amounts to 93,237 million cubic feet. Their effect on the navigation of the Mississippi in the vicinity of St. Paul, 350 miles below the reservoirs, is stated



Regulation work at Wesley Chute, French Broad River.

in reports to be about 1 foot to 14 inches increase in depth at low-water stages, and about 50 miles further down the increase in depth is so slight as to be negligible. The main benefit of these reservoirs has been in the development of large water powers at St. Paul and Minneapolis; and it has been asserted that the claim that their construction would aid navigation was only a subterfuge urged by the power companies to secure private benefits at public expense. It is a matter of fact that the first examinations and surveys for these reservoirs were made at the expense of the companies having water rights, as they were to be large beneficiaries of any such work the Government might institute, and were very eager to have the project undertaken at public expense. It appears now, after the lapse of about twenty years, that the benefits derived from these reservoirs are far more important in the direction of the development of water power than for navigation. It was proposed in 1881, and an examination with reports was ordered by Congress with that in view, that this system of reservoirs be extended to the Fox, Wisconsin, and Chippewa rivers; but after several examinations by two separate boards of engineers this was definitely decided against on the ground that the probable benefits were too indeterminate and the cost disproportionately large, both boards deeming the usual methods of improvement surer and better.

The theory of holding back the flood waters of our rivers, to be released later during low-water stages, so as to conserve the water for power, for navigation, and for other purposes, is plausible and seductive at first glance. The practical application of the theory, however, immediately introduces serious and insurmountable difficulties. If the waters now going to waste in our rivers at high stages and causing such widespread damage along the valleys could be economically withheld so as to equalize the flow, thus contributing to various industries, it would undoubtedly be an improvement greatly to be desired. These ideas have been promulgated of late in extravagant terms and with much persistence by various engineers, few of whom, however, have had any practical experience in the improvement of rivers or in the control of floods. They maintain that the reservoirs will effect a material reduction in the height of the crests of the various floods in the Ohio and Mississippi rivers,



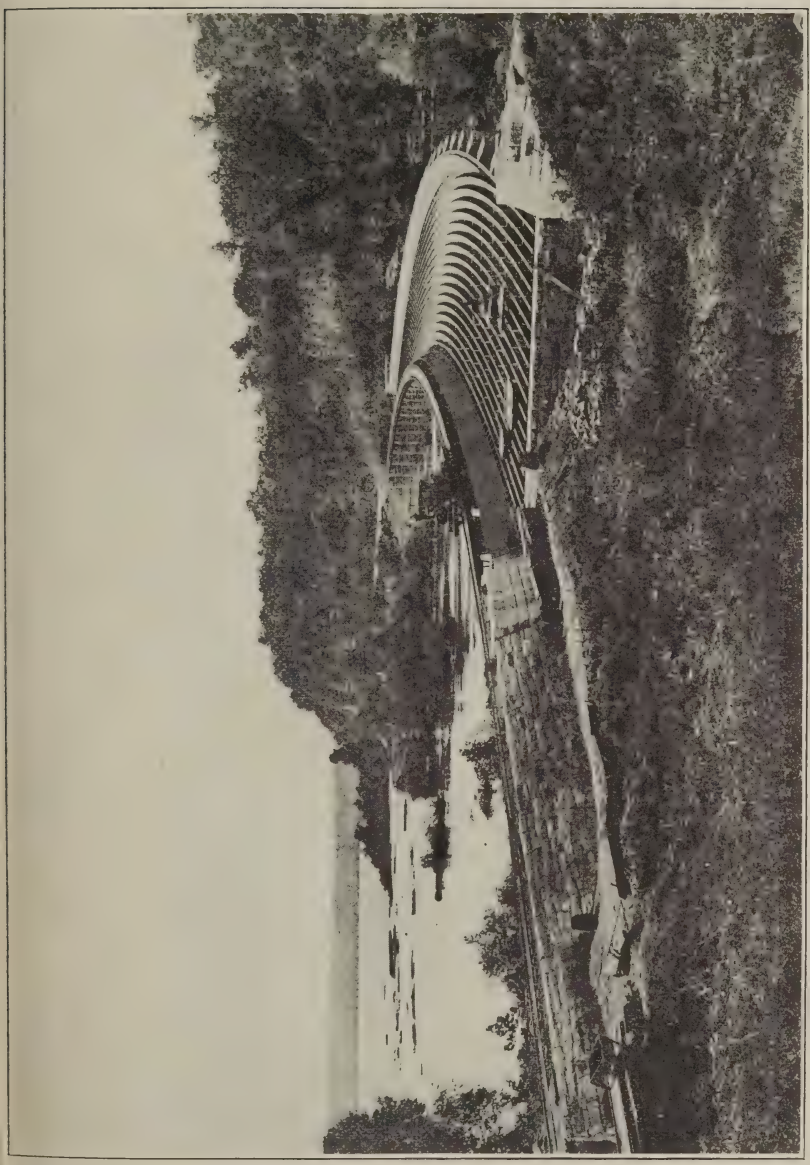
Temporary Tripod Dam used in exposing the river bottom for rock excavation at Little Muscle Shoals, Tennessee River.

and thus prevent the overflowing of vast areas and permit them to be more readily reclaimed and used. The damages wrought by extreme high water, they assert, would be greatly reduced; thereby causing a further enormous saving. Then by liberating the stored water during the low stages the flow would be equalized, so that more water would pass downstream when navigation would ordinarily be difficult; thus increasing the navigable depths to a point where the usual methods of improvement would no longer be necessary.

The advocates of this improvement state also that in this manner enormous water power may be created which may be transmuted into electrical energy and sold at a sufficient profit to pay a large proportion of the cost of the dams, and altogether the investment necessary is represented as being a paying one for the Government. These enormous reservoirs, they claim, would further serve to benefit other industries, such as fisheries, render irrigation practicable, result in the clarification and purification of polluted streams, supply municipalities with water, and enable the forestry service to restore to the mountain sides the growths that protect these slopes from erosion and withhold the run-off, still further diminishing the danger of floods. These comprehensive claims are like the "combination tool, the joy of the inventor but the despair of the user."

These advantages would be of enormous benefit, provided they could be accomplished at reasonable cost and without disadvantages of far greater importance. In the beginning it appears that, although the theory of reservoirs has been known in well-settled countries abroad for upward of two centuries, the extension of this system has never been attempted on any large scale nor has it received any favorable comment from experienced engineers. In fact, it has long been condemned by such distinguished river engineers as Vernon-Harcourt, Malézieux, Milnor Roberts, General Abbot and Colonel Merrill, besides many others.

The experience of the past has shown that the theory is impracticable and unsuccessful; and its application has been abandoned after ample trial, both at home and abroad. The system often requires dams of enormous heights (some proposed for the Tennessee River by the Geological Survey being upwards of 200 feet high) and of great lengths, with vast bodies of water impounded in the upper regions of the streams where any accident would be a great calamity. The results of a breached reservoir dam were seen in the



Shoal Creek Aqueduct, Muscle Shoals Canal. Canal trunk empty.

case of the Johnstown flood, in Pennsylvania. For the French Broad River, the largest tributary of the Tennessee, the engineers of the Geological Survey have suggested a dam three times as high as the one which caused the Johnstown disaster, and holding back four hundred times as much water.

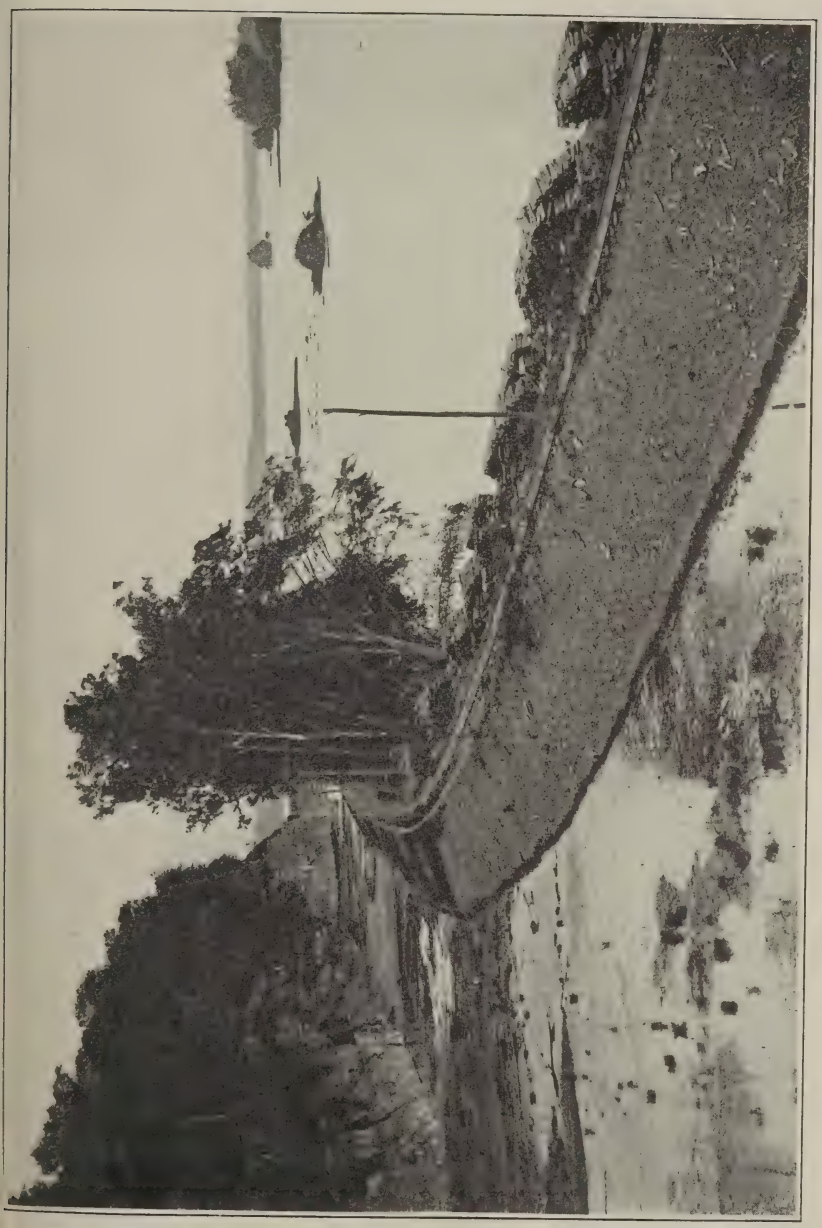
This reservoir method has been found efficient in controlling floods wherever used, and has been unsatisfactory in increasing navigable depths. The main successful use to which the reservoirs have ever been put is in the production of water power at sites where power could easily be marketed. Should such works ever be constructed for the benefit of navigation, it seems undeniable that they would cause great damage to the towns, railroads, and other industries in the valleys to be submerged; would prevent communication across these valleys, drown out mines, destroy the productive power of the fields covered, transfer the flooded areas from the lowlands, where ocasional floods are expected, to the high grounds, which would be permanently submerged, and arouse a series of contests with riparian owners requiring many years in all probability to settle. Whether the present owners of these basins would ever peaceably submit to the use of their property for storage reservoirs even if offered liberal compensation therefor, is a matter of serious doubt. It seems questionable whether, under our form of government, any large areas could thus be taken from private ownership.

The greatest objection, however, to this system appears to be its enormous cost and the indefinite time required for its execution, both of which are far beyond the reach of ordinarily accurate estimates and would probably exhaust the patience of the people. For these reasons the plan of improving the Ohio River by reservoirs, when examined into in 1873, was abandoned in favor of the more satisfactory, direct, and economical method of locks and dams.

A reservoir project of a general nature has been recently promulgated for the Ohio River basin by some of the officials of the Geological Survey, the cost of which has been placed about $125,000,000. A detailed examination of these plans and visits to the sites show that this estimate is grossly inadequate, the indications being that the cost will be more nearly ten times these figures.

The use of reservoirs as an exclusive means of improving the navigability of rivers is subject to the following criticisms:

1. They have been found inefficient and unsuccessful wherever tried.



Muscle Shoals Canal under construction; showing type of embankment used.

2. Unsafe and attended with great risk, owing to the enormous dams required and quantities of water impounded.

3. Of doubtful legality, and a probable source of much litigation, owing to infringement of riparian rights.

4. Enormously expensive compared with other methods.

5. Slow in construction to a useful stage.

6. Soon filled with sediment in many localities.

7. Not advocated by river engineers.

8. In operation, if they should be constructed, they would present a problem too stupendous and complex for successful operation.

Although this method of improving streams has been resurrected from time to time and advocated by enthusiastic supporters in terms of extravagant praise, it seems improbable that it will ever be extensively used; although it is possible that as an auxiliary in certain rivers it may be found desirable where the natural conditions are eminently favorable.

### CONTRACTION WORKS.

The second method of improving rivers, as mentioned above, is by the contraction of the channel. The effect of contraction is to raise the water surface locally, compelling the river to pass through a narrower opening than before, thus raising the surface and increasing the head, which in turn increases the slope below and usually the velocity.

Inasmuch as all improvements of this character are for low-water discharges in cases where continuous navigation is sought, it follows that only rivers having a considerable flow at such times, and moderate slopes, are suitable for this kind of treatment. The works must furthermore be so designed as not to interfere materially with navigation at higher stages. Dikes, sills, training walls, and other contraction works must therefore be kept low and so disposed as to offer the least cause for trouble at the higher boating stages.

It may be broadly stated, as a general rule, that all rivers scour their banks and bottoms more or less, until there is produced an equilibrium between the scouring effect of the current, on the one hand, and the resisting effect of the bottom, on the other. A reduction of the velocity of the current below this will cause a deposit, if sediment is in suspension. Whenever a river is contracted by artificial means, the increased velocity caused thereby tends to produce a new scour, until a new equilibrium is established sooner or later, depending on how easily the bottom and

Muscle Shoals Canal. Waste weir opposite Six Mile Creek, to pass excess of water due to high stages in the creek.

banks can be scoured away. It is thus clear that a contracted cross-section in a river of unstable bed can only be temporary, and will gradually increase, through the deepening or widening of the channel by erosion, until the area of the original cross-section or a new equilibrium among the acting forces is reached. Works for protecting the bottom and banks are therefore to be carefully considered in all such improvements, wherever the bed is not of resisting material. We invariably find, when the river bed is movable, that a pronounced scour takes place opposite the contraction works, and, on the other hand, wherever the bed is naturally sufficiently resisting or is adequately protected, the contracting works raise the surface and increase the depth, and if properly designed to prolong the fall over a sufficient distance, may and should decrease the velocity. On these general principles all open-channel regulation is based.

*Formulas.*

For many years efforts have been made to obtain simple empirical rules for the flow of water in open channels, and, although the science of hydraulics is by no means exact, it is usually sufficiently useful to warrant applying the formulas proposed by eminent engineers, to see whether they will not check with experience, and confirm plans based on previous successful application of theories.

The flow of water in rivers and canals was early studied by Chézy, the eminent French engineer, who proposed the now well-known formula, $V=C\sqrt{R\,S}$, as an expression of the relations existing between the velocity, depth, shape of channel, and slope. In this formula, V represents the mean velocity of the stream, C a constant depending on the physical characteristics, R the mean hydraulic radius, and S the slope. This formula, it is believed, would be exact could we determine C without error. Complex expressions for values of C have been proposed by Kutter and Ganguillet, resulting in what has now come to be regarded as the most reliable formula for stream flow, ordinarily known as Kutter's formula. It depends to an important degree on the roughness of the bed and banks, a value impossible of exact determination.

We know that the quantity of water flowing past any cross-section is equal to the area of the section multiplied by the mean velocity; a relationship that may be employed in developing a formula for use. This rule may be expressed in the equation, $V=\frac{Q}{A}$ in which V equals the mean velocity in feet per second, Q the discharge in cubic feet per second, and A the area of the section in square feet. In broad, shallow rivers, such as are usually im-

proved by contraction, the hydraulic radius may be assumed without material error to be equal to the mean depth, and the wetted perimeter equal to the width. The area of any section may likewise be assumed to be equal to the product of the width by the mean depth. With these assumptions we develop the following equation: $W=\frac{Q}{C\sqrt{R^3S}}$ in which W represents the width, Q the discharge, R the depth, S the slope, and C the constant depending on the characteristics of the river. With this equation it is easy to construct a table of channel widths applicable to a discharge of 1,000 cubic feet per second, for various depths, slopes, and values of C. With such a table we may obtain the width for any discharge, provided we know the depth desired, the slope, and the value of *n*, the coefficient of roughness of the river.

Too much reliance, however, must never be placed upon hydraulic formulas, and attention is drawn to the fact that such a table will depend primarily upon the value assumed for *n*, the coefficient of roughness in Kutter's formula. A small change in *n* makes a relatively large change in C, and as *n* is never the same for any two localities the values of our equation must be accepted and applied with caution.

Such a table has been made for the Upper Tennessee and Middle Tennessee, based on a value for *n* of 0.030, and is given as follows in the Annual Report of the Chief of Engineers, 1902, page 1774:

*Probable mean and maximum velocities and mean widths of channel for flow of 1,000 cubic feet per second, resulting from the conditions shown.*

[Velocity in feet per second. Mean width in feet.]

| Coefficient (C). | Mean depth (D). | Fall of water surface in feet per mile. 0.50 | 0.75 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fall of water surface in feet per 1,000 feet. .095 | .142 | .189 | .284 | .379 | .473 | .568 | .663 | .757 | .852 | .947 | |
| 65.2 | 3.0 | 1.10 | 1.35 | 1.55 | 1.90 | 2.20 | 2.46 | 2.69 | 2.91 | 3.10 | 3.30 | 3.48 | Mean velocity. |
| | | 1.53 | 1.87 | 2.16 | 2.64 | 3.05 | 3.41 | 3.74 | 4.04 | 4.32 | 4.58 | 4.83 | Max. velocity. |
| | | 303 | 248 | 215 | 175 | 152 | 136 | 124 | 115 | 107 | 101 | 96 | Mean width. |
| 67.0 | 3.5 | 1.22 | 1.49 | 1.72 | 2.11 | 2.44 | 2.73 | 2.99 | 3.23 | 3.45 | 3.66 | 3.86 | Mean velocity. |
| | | 1.69 | 2.06 | 2.43 | 2.92 | 3.36 | 3.76 | 4.12 | 4.45 | 4.75 | 5.04 | 5.32 | Max. velocity. |
| | | 234 | 191 | 166 | 135 | 117 | 105 | 96 | 88 | 83 | 78 | 74 | Mean width. |
| 68.3 | 4.0 | 1.33 | 1.63 | 1.88 | 2.30 | 2.66 | 2.97 | 3.26 | 3.52 | 3.76 | 3.99 | 4.20 | Mean velocity. |
| | | 1.83 | 2.24 | 2.58 | 3.16 | 3.65 | 4.08 | 4.47 | 4.83 | 5.16 | 5.48 | 5.77 | Max. velocity. |
| | | 188 | 154 | 133 | 109 | 94 | 84 | 77 | 71 | 67 | 63 | 60 | Mean width. |
| 69.3 | 4.5 | 1.43 | 1.75 | 2.02 | 2.48 | 2.86 | 3.20 | 3.50 | 3.79 | 4.05 | 4.29 | 4.53 | Mean velocity. |
| | | 1.96 | 2.30 | 2.77 | 3.39 | 3.92 | 4.37 | 4.79 | 5.17 | 5.53 | 5.87 | 6.19 | Max. velocity. |
| | | 155 | 127 | 110 | 90 | 78 | 70 | 64 | 58 | 55 | 52 | 49 | Mean width. |
| 70.0 | 5.0 | 1.53 | 1.87 | 2.15 | 2.64 | 3.05 | 3.41 | 3.73 | 4.03 | 4.31 | 4.57 | 4.82 | Mean velocity |
| | | 2.08 | 2.54 | 2.93 | 3.60 | 4.16 | 4.64 | 5.08 | 5.50 | 5.87 | 6.23 | 6.56 | Max. velocity. |
| | | 131 | 107 | 93 | 76 | 66 | 59 | 53 | 50 | 46 | 44 | 42 | Mean width. |
| 71.2 | 6.0 | 1.70 | 2.08 | 2.40 | 2.94 | 3.40 | 3.79 | 4.16 | 4.49 | 4.80 | 5.09 | 5.37 | Mean velocity. |
| | | 2.30 | 2.82 | 3.25 | 3.99 | 4.61 | 5.15 | 5.64 | 5.09 | 6.51 | 6.91 | 7.28 | Max. velocity. |
| | | 98 | 80 | 70 | 57 | 50 | 44 | 40 | 37 | 35 | 33 | 31 | Mean width. |

From this may be found at a glance the theoretical width for any discharge and slope, as well as the mean and maximum velocities.

*Objects Sought.*

All rivers may be described in general as consisting of a series of pools of deep water with velocities less than the mean, separated by shoals having shallow water, considerable fall, and velocities greater than the mean. The object of all this class of improvements is to equalize as far as may be practicable the fall over these shoals, so as to increase the navigable depth to a useful point and maintain such low velocities as will admit of easy navigation.

The careless excavation of shoals without providing for contraction to hold up the water surface has been repeatedly shown to be a dangerous proceeding, whether the excavation is caused by scour or by artificial means, inasmuch as it increases the area of cross-section and lowers the level in the pool immediately above, often exposing shoals not before troublesome. This method of improvement must not be attempted except in rivers of small slope and large flow, and then with caution.

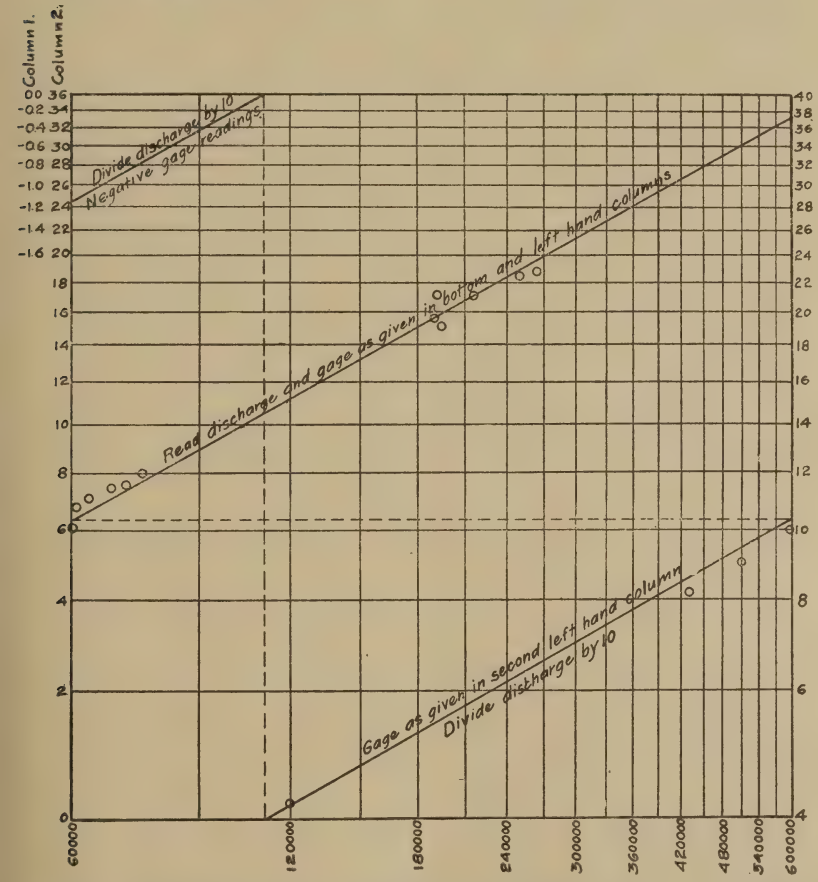
It may therefore be broadly stated that regulation by contraction must ordinarily be based upon a permanent bed, either of resisting material, such as rock or compact gravel, or by artificially protecting the bed by sills or submerged weirs. The object to be achieved in regulation work similar to that on the Tennessee River should, in general, not be to increase the depths by lowering the river bed, but to increase the depths by raising the water surface, and to distribute the slope over a greater length.

*Survey.*

Before the work of improvement is commenced in any river, careful study is necessary, and a number of physical characteristics must be ascertained. Besides a complete survey of the river as a whole, there must be made minor surveys, to a larger scale of each shoal to be improved. It is very desirable in these minor surveys to show the shoal in detail by drawing the under-water contours, especially that one indicating the depth of improvement desired. A channel profile of the river bottom, showing also the surface of low water and the velocities observed opposite each important change in slope, taken preferably with a current meter, is necessary in determining the location of the works. Gauges in the pool above and in that below, situated too far away to be easily

Tennessee River. Chattanooga to Riverton. Muscle Shoals Survey.

Diagram showing the Discharge of the Tennessee River at Florence, Alabama. Prepared under the direction of Maj. Wm. W. Harts, Corps of Engineers, U. S. A., by Mr. F. I. Louckes, Junior Engineer, October, 1908.




Note: Observations are indicated by a small circle (o). Gauge readings shown on the left of the diagram correspond to discharges as indicated in the bottom figures.

The right-hand column is for plotting purposes only and should not be used for reading discharges.

affected by the works, together with several other gauges well distributed between these extreme ones, should be read daily during the progress of the work to ascertain the results of the construction as it proceeds. Before commencing work the level of the water surface desired should be drawn on the profile, and the approach to this line, as indicated by the gauge readings, carefully watched.

There must also be made a study of the discharge at low-water stages, these being the periods when rivers are ordinarily most obstructed by shoals. These discharge measurements involve a careful survey of the river at a number of critical places to obtain areas of cross-sections, and observations of the river current to determine the mean velocities corresponding to the location of the cross-sections. If enough current observations are made, it will not be difficult to plot the curve of discharge for any of these sections, making due allowance for inaccurate observations and other information which can not be definitely ascertained. Logarithmic cross-section paper is especially suitable for these discharge curves, as the scale is much larger for low-gauge readings, where the corresponding discharge is most important to know, and, further, because all curves expressible by any equation of a higher degree than the first become straight lines easily located and drawn.

From this curve some assumed low-water must be adopted, to be used in designing the work. On the Tennessee it has been assumed, in this manner, that the zero low-water discharge at Knoxville is 2,500 cubic feet per second; at Chattanooga, 5,000, and at Riverton, 10,000. These correspond fairly well with the low-water observations at these points, but are below the *ordinary* low-water discharges, and our tables will therefore give somewhat narrower channels than are needed during the usual dry periods. Dikes are never entirely tight, however, and as time goes on they are less efficient; so that these zero discharges may usually be taken without serious error. Inasmuch as it is difficult to ascertain where the increase in quantity of discharge occurs in all instances, it is customary on the Tennessee River to assume the discharge as increasing uniformly between the points mentioned as we proceed downstream. We can in this way find a quantity which may be relied upon as fairly accurate for any point in the river.

It may be stated as a general rule that the bottom of the Tennessee River is of resisting material, consisting as it does of rock overlaid by coarse and cemented gravel. Its improvement, therefore,

does not usually present as many difficulties as are encountered in rivers with unstable beds. Bank protection is also more easily provided for.

*General Cases.*

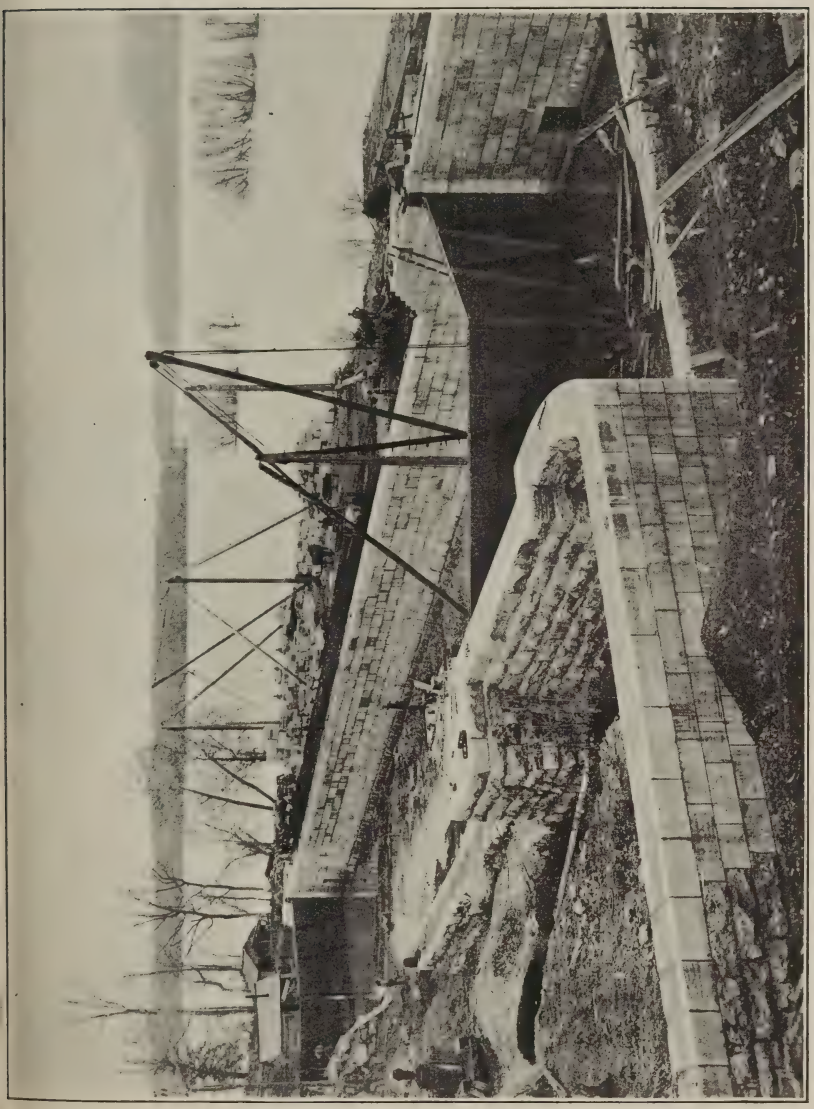
In examining the Tennessee River with a view to its improvement a number of cases present themselves, of which two are the most important and general, the others being special. The first of these is where the river is too wide, the depths insufficient, and the velocities low; and the second is where the fall is concentrated over a hard bottom, with small depths and high velocities. In the first instance all unnecessary channels back of islands should be closed with dikes, and then the water of the reach concentrated in a selected place by means of contraction works, seeing to it that the exposed bank and the bottom are protected from the resulting scour. In the second, the surface must be raised by contracting dikes and the slope carried downstream over a sufficient distance to equalize the fall and reduce extreme velocities.

*Limiting Slopes and Velocities.*

Extreme velocities must be avoided, and it is usual to assume some limit, not to be exceeded, which depends on the stream and the class of vessels using it. It has been customary on the Tennessee River to assume that the velocities in improved channels should not exceed 5½ feet per second, and that improved places in rapids and shoals should have a width of not less than 150 feet of available channel, and that slopes should not exceed 5.0 feet per mile. The depths which we are endeavoring to secure are a minimum of 5 feet at low water from the mouth, at Paducah, up to Chattanooga, and a minimum of 3 feet from Chattanooga to Knoxville. It is the intention to secure these depths by contraction works, assisted as far as practicable by dredging and rock excavation, except where the approved projects provide for lateral canals or complete canalization.

*Kinds of Works.*

All contraction works on our rivers consist of three types: (1) spurs, (2) dikes or training walls, and (3) sills. These, when combined with bank protection, form the usual means of effecting the improvement desired. Dredging is often necessary as an accessory improvement, and frequently rock excavation in the shoals is needed to remove objectionable reefs. This work must always be attended by a due amount of contraction, to avoid lowering the pool levels.



Lock A, Muscle Shoals Canal, under construction.

Each method of contraction has its advocates, and each has its advantages. Spurs consist usually of rows of random stone built in a straight line out from the bank, making nearly a right angle with the thread of the river, but usually inclined slightly upstream to prevent the overfall from washing away the banks below and to throw the water toward the middle of the river. Dikes or training walls are likewise built of rows of random stone, but are usually in curved lines following the thread of the river. Sills are usually laid across the bottom in straight lines at places where it is necessary to prevent undue scour, or where we wish to diminish the slope of the water surface and contract the channel at the same time. Although each method has its advantages, it seems the part of wisdom to use combinations of all three.

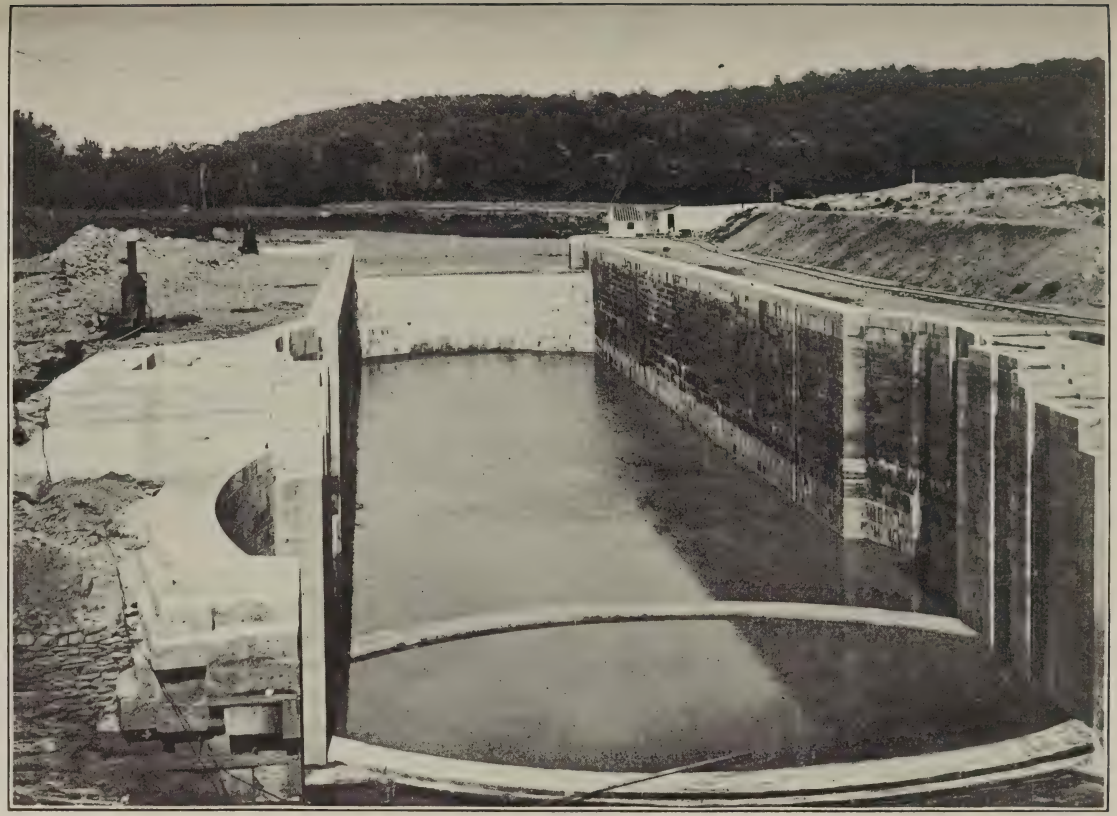
*How Built.*

Spurs and dikes are usually built of rock dumped from barges along a well-marked line. They are usually from 3 to 10 feet wide on top, depending on the strength needed to resist drift, ice, or strong currents. They have natural slopes on the sides, and are usually brought about 2 feet above low-water level. Where no ice is to be feared, small stones may frequently be used; the dikes on the Upper Tennessee standing better, it is reported, when made of small stones weighing from 100 to 500 pounds than when constructed of larger pieces. Dikes must be made substantially watertight, by calking with spalls or gravel, to get the best effect. Sills are made by dumping rock in a straight line across the channel until the work has reached the desired elevation. Sills must be placed with extreme care, and should not be built unless their use is indispensable and clearly indicated.

*Principles of Design.*

In applying any of our principles at a specific locality, the survey showing the bottom contours and the profile of the water surface, together with the tabulated current observations, must be studied. The prospective channel widths should be calculated and the proposed lines laid out with much care. These should be checked on the ground.

These works, if located too high on the shoal, will raise the water level in the pool above the shoal, and thus increase the fall over the obstruction—adding to the difficulty instead of remedying it. This is a common error. If too low down, the effect will not



Lock of Colbert Shoals Canal, Tennessee River, under construction. Lift, 26 feet.

extend over the entire shoal. The lower end of the work must usually also be placed where there is deep water, to avoid the formation of a new shoal due to the change in conditions and the difference in slopes and velocities. The training walls or dikes should be prolonged, as far as necessary, to distribute the fall over a greater distance and thus reduce the surface velocities. The friction along these dikes may be relied on for considerable effect in holding back the water. From 1 to 2 feet increase in depth is all that can ordinarily be expected from contraction works.

Works of this character should invariably be placed on the convex side of the stream, leaving the concave bank as a guide to vessels in using the channel. This concave bank should be protected at the toe, or over a greater height if found necessary. Contraction works placed near the concave bank introduce complications in handling boats, the draw over the dikes when submerged, and their trace, making it difficult for boats, especially in the wind, to keep from fouling them. Under no circumstances should training walls or dikes be placed on both sides of the channel at the same place. Such a construction would render navigation very difficult, especially for steamboats having barges in tow.

In designing works for open-river improvement the following principles should always be borne in mind:

1. That all nontidal rivers consist of successions of pools and shoals.

2. That ordinarily no improvement of shoals must be permitted that will lower or raise materially the levels of the pools; but that the slopes at the shoals must be lengthened by distributing the fall over a greater distance and the depth thereon increased by contracting the flow.

3. That the banks and bottoms must be protected against scour wherever necessary.

4. That contraction to secure greater depth on shoals must not cause an increase of velocity beyond a safe limit for navigation.

5. That dredging and rock excavation should be resorted to as an auxiliary whenever the expense of using these aids would be less, and whenever the improvement possible by contraction is not sufficient.

### CANALIZATION.

The third method of improving nontidal streams is by canalization. The object of canalization may be briefly stated to be the concentration of the fall of the river at various selected points by

Lock No. 1, Cumberland River, nearing completion.

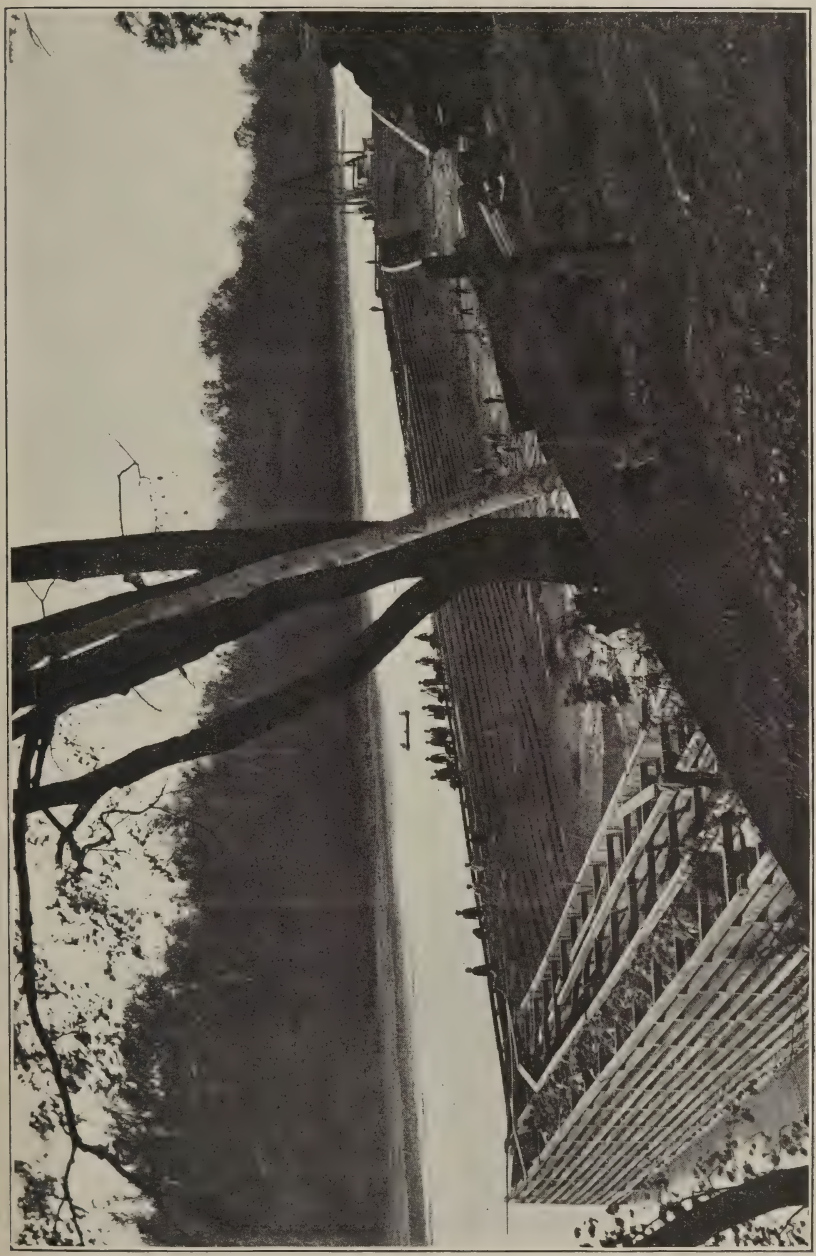
means of dams creating artificial pools between these points in which there will be ample depths for navigation; boats being passed from one pool to another by means of locks. This method of improvement has been extensively employed both in this country and abroad for many years, with eminently satisfactory results. The advantages of this method are that it is positive, a close estimate of cost can be made beforehand, and an adequate improvement is accomplished whenever a lock is completed; a certain length being added thereby to the navigable stream, depending upon the slope of the river and the height of the dam. It has some disadvantages, also, such as raising the low-water surface and thus subjecting adjacent lands to overflow, interposing delays to the movements of vessels (to the extent of the time required for the passage of locks), introducing new conditions of flow in the river caused by the reservoir action of the pools, and the cost of the system. All these have, however, in many cases, been outweighed by the direct advantages obtained.

Locks and dams are necessary in streams of small flow or of high slope, if continuous navigation is sought. The height of lift practicable, the depth necessary over the miter sills, and the method of connecting the structures with the banks all depend upon the character of the stream and the nature of the banks and bottom. A discussion of this method of improvement usually narrows itself down to a consideration of the details of the locks and dams, as the general principles are simple and their applicability usually easily determined.

*Locks.*

No more satisfactory method of lifting vessels from one level to another, for use in streams where occasionally high water passes over the entire work, has ever been devised than the old system of locks by which the vessel is enclosed in a short canal or chamber and the surface of the water between the two pools changed by admitting or releasing water in this chamber through valves. It is inexplicable why this simple device was not discovered by the ancient Greeks, Romans, or Egyptians, but it was not until the fourth century that it was originated by Leonardo da Vinci. Other methods have been tried since, but nothing has yet been found approaching this design for simplicity, ease of operation, and durability.

Although the principle of locks is simple, there are many details of their construction that require careful computation and good



Cofferdam for Lock No. 4, Cumberland River; showing three chambers, two for rock and one for clay puddle.

judgment. The most serious question to be settled is that of foundations; the difficulties increasing as we change from durable rock, such as is found on the Tennessee River, to yielding mud, as is found at the Plaquemine Lock, in Louisiana. One wall of the lock is ordinarily designed in the bank as a retaining wall for earth, the other being designed in the river to withstand water pressures. The upper miter sill must be designed for the pressure due to the head caused by the upper gates, and the walls near the ends of the lock must be widened into what are called buttresses, to provide for the necessary filling and emptying valves and culverts and to resist the pressure of gates. Ordinarily, the lock walls are made of sufficient height to extend above high water, or else are built high enough so that when they are submerged the river will either be navigable by permitting vessels to pass over the dam or will be at so high a stage as to cause a suspension of boat traffic.

It has been observed that the water below a dam rises more rapidly than that above; an increase of 1 foot in the stage above the dam giving in many cases an increase below the dam of more than 2 feet. This ratio has been carefully plotted for the Cumberland River, where it is found that the curves of rise may be plotted in comparatively straight lines, the ratio of increase below the dam for each foot above the dam having been found to be 2.25 at Lock A, 2.36 at Lock 1, and 2.15 at Lock 2. The ratios would, of course, likely differ for each river, and perhaps for each lock in the river. It will be seen, therefore, that as the river rises the surface below the dam will overtake that above when the lift is low, and then the entire surface will have the normal slope of that section of the river, and the effect of the dam will be obliterated. Vessels can then pass freely over the dam.

It is very necessary on such streams as the Cumberland and the Kentucky to provide for navigation at high-water stages. The height of the lock walls above the dam sufficient for this purpose is known as the "guard," and can be foretold only with considerable difficulty.

The thickness of the walls is determined by calculation, assuming the most unfavorable conditions of overturning pressures. The land wall is usually designed as a retaining wall, and many theories have been advanced and equations proposed for its safe design, among which are those of Rankine, Coulomb, and Weyranek.

It has been claimed by some, among whom we find Sir Benjamin

Baker, that these require for their satisfaction too great a thickness of the base, and accordingly he substitutes a theory of liquid pressure, with "rules of thumb," which have been found in his practice to be better suited to the average conditions. A compari-

Concrete Lock under construction at Hales Bar, Tennessee River. From the bank overlooking the lock.

son of many lock walls in this country shows that the ratio of the average width of the cross-section of the land wall in proportion to the height varies from 32 per cent to 42 per cent, with an average of about 35 per cent. Sir Benjamin Baker's rule for ordinary earth is 35 per cent, when not surcharged.

The tops of river walls and of land walls need be only thick enough for safe and convenient use by the men who are to operate the lock. Ordinarily, this thickness should not be less than 5 or 6 feet for small locks, increasing for larger ones.

Practically all the materials of which locks were formerly constructed, such as brick, timber cribs, and stone masonry, have now yielded to the use of concrete, on account of economy; the construction being almost invariably on designs of "gravity" section rather than of reinforced concrete. It has been determined by actual experience that lock walls and the accessory features can be more satisfactorily, more economically, and more quickly constructed of "mass" concrete (or "cyclopean") than by the use of reinforced sections.

*Dams.*

In deciding whether to use fixed or movable dams there are conditions of a complex nature to be considered. In the case of fixed dams the cost of maintenance is a minimum, the cost of operation low, and the first cost of construction much less than when movable dams are used. There are cases, however, in streams carrying much drift or heavy sediment, where movable dams may be necessary. Futhermore, movable dams afford a greater control of the river, so that the period of open-river navigation when the locks need not be operated is lengthened by contracting the channel within navigable passes. It permits a less height of lock walls and cheaper lock construction.

For most of our streams of moderate size fixed dams have been found more satisfactory. The danger that the pools might fill up by sediment brought down at high stages has not been found so formidable as was anticipated. In the Kentucky River, where such dams have been in operation over thirty years, no appreciable filling has been noted, and, on the contrary, difficulty is experienced in holding the "backing" behind the dams against the scour of high water. The same experience has been reported on the Green and Muskingum rivers. It may therefore be safely assumed that in all cases where movable dams are not plainly indicated by local conditions the fixed dam will be the more satisfactory structure. Movable dams are of so many types, applicable to varying conditions, that a description of them here would prolong this paper beyond a reasonable length. This is a definite and separate branch of the subject and has been made the object of much study.

The most important point to settle in connection with a fixed

dam is the foundation. Owing to the great disturbance created by the fall of water over even a moderately high dam, it is necessary that the stream bed, if not composed of rock, should be adequately protected to avoid the reaction of the falling water known as "backlash."

The design of dams for overfall weirs has been theoretically computed, but the calculations involve so many uncertainties that they must finally be tested by the rule of successful experience. It is

Concrete Lock under construction at Hales Bar. Lock pit looking upstream, showing concrete forms and nature of foundation.

comparatively simple to design a triangular mass of concrete sufficiently strong to withhold a quiet head of water against its face; but when the water passes over, as happens in our canalized streams, many other conditions arise affecting the stability.

First, the top width must be enough to resist wear and shocks, as of drift. Second, there is a suction or vacuum effect in the downstream face caused by the flow of water, the extent of which has never been investigated with care. That this effect is some-

thing, however, is plain; and, in fact, some engineers have estimated it to amount to as much as one-third of the depth on the dam. Its direction is unfavorable, since it operates as an overturning force. Third, the sediment that collects behind a dam may increase the pressure beyond the 62½ pounds per cubic foot usually allowed for water pressure; and, indeed, this may increase, depending upon the character of the material, up to as much as 100 pounds per cubic foot. Fourth, it is impossible to keep some water from reaching points under the dam. It is plain that in all such cases an upward pressure is produced which may be as much as that due to the head, and a tendency to overturn occurs. When the dam is submerged by a heavy sheet of water, if any water pressure reaches points under the foundations, there is a diminution of weight in the dam due to the effect of flotation.

Other considerations, also of an unknown nature, may be introduced, such as the effect of surging waves, so that it will be seen that the design of an overfall dam involves many conditions that are inexact. It has been found desirable, however, by some engineers, in designing overfall dams to make the factor of safety approximately 2 for a combination of the most adverse conditions, including the reduction of the weight of the masonry by the weight of water displaced, the suction under the sheet of overfalling water, and the extra liquid pressure against the upstream face. In the case of the ordinary concrete dam this corresponds to a factor of safety of considerably over 3 for normal conditions, when only static heads are considered.

A comparison has been made of a number of overfall dams showing that the relation of the mean thickness to the height varies in the best designed dams from 60 per cent to 80 per cent. The shape of overfall dams, too, has considerable to do with the passage of water. If the downstream slope is too steep the water pouring over the dam at ordinary stages will have a tendency to produce a tumbling action at the toe, which gives logs and drifts no opportunity to escape. Some dams, more particularly those constructed of timber cribs, have been badly battered by drift. Where the slope on the downstream side is flatter, the tendency of drift to pass along down the river has been observed to be greater. It was found by Colonel Merrill, on the Muskingum River, that this slope should be 1 on 4 as a minimum. This, it is reported, corresponds to the rule of the Ponts et Chaussées, in France. Building solid concrete dams, however, with such a flat downstream slope would

be unduly expensive, and more economical sections are usually adopted. An ogee shape is said to reduce the vacuum effect.

Hollow dams of reinforced concrete have not yet been used long enough to make their use in navigable streams warranted; although designs have been made in which the flat downstream slope is retained and the use of concrete throughout depended upon. Some designs involving the downward pressure of the water to increase the stability have been built in special places. The greater cost of this design, including the forms, and its newness, have prevented its more general use up to the present.

*Abutments.*

Abutments must be so designed as to prevent the water from flowing around the end of the dam opposite the lock, and to protect the bank sufficiently to prevent undue scour caused by reaction at high stages.

The usual abutment consists of a retaining wall for the earth bank behind, parallel with the flow of the stream and of sufficient height to contain the water at all stages when the reaction of the overfall might be feared. This varies in different localities, and the height to be adopted depends upon the river.

Each abutment also includes one or more wing walls at right angles, running into the bank a sufficient distance to prevent seepage of water around the abutment and to make a thorough connection with the bank.

Wherever banks are subject to scour, they must be protected by substantial paving up to and above high-water mark and extending a considerable distance up and down stream to prevent the water from "flanking" the end of the dam by its erosive action. This protection usually consists partly of hand-placed paving and partly of random rip-rap, both placed on a bed of spalls to prevent underscour. It has been found that large riprap on banks of earth exposed to wash is not adequate in itself, but that a bed of spalls from 6 to 9 inches thick when placed below the riprap acts as a mattress and will stop the scouring action of the currents.

*Gates.*

Gates for locks on the Tennessee River are of the mitering pattern and are all built of steel. The most recent are those designed for Hales Bar Lock, and consist of rectangular girders built up of structural shapes (the span being too great for I-beams) in

what is known as the horizontally-framed type. The strain is transmitted by these girders to the side buttresses through metal meeting-face plates. Vertical members are for construction purposes only.

The experience at Muscle Shoals Canal confirms that at other places, and demonstrates the fact that wooden cushions for sills, miter posts, and quoin posts are not satisfactory; a little wear permitting a small leak which in time wears away both the wood and the masonry. In all work now being designed on both the Tennessee and Cumberland rivers, it is proposed to use metal quoin and miter posts and metal sills.

The gates for the Colbert Shoals Canal lock are curved in section. The upward pressure on these gates is greater than the weight of the gates, and to avoid intricate shop work in making the bottom girders overlap the miter sill in order to reduce this pressure, it was considered more economical and desirable to place the skin on the downstream flanges of the girders. Furthermore, in order to make the lowest girder and the sill fit, it was determined to have the miter sill made at the shops and carefully fitted there before being shipped, and then to place the sills in sections in the stonework of the lock, any adjustment being made between the sill and the stonework.

The experience at the Cascade locks, Columbia River, shows that by metal meeting-face plates a more perfect closure may be obtained than when wood is used. When locks do not exceed about 60 feet in width, rolled eye-bars may be used instead of built-up girders, the meeting-face plates being carried by cast-steel chairs opposite the ends of the girders. The spacing of the girders is made proportional to the water pressure.

It may be stated that it is good practice, in designing gates, to adopt minimum thicknesses of rolled shapes for gate construction and then to purchase the gates for a lump sum rather than by the pound. The tendency of manufacturers, when gates are purchased for a lump sum, is to reduce the areas of cross-section below what is contracted for. On the other hand, when gates are purchased by the pound, the tendency is to increase these areas above what is necessary so that the weight may be made greater. By contracting for the gates for a lump sum and using minimum cross-sections for the strength deemed necessary, these difficulties are avoided.

Two of the most intricate portions of a gate to design are the

pintle and the anchorage collars. It is customary to make the pintle of forged steel, and the socket in which it rests of steel castings. The connection between the gate and this socket is a detail of considerable complexity, to secure strength and at the same time permit closure and thus prevent leaks. It is customary to set the center of rotation an inch or more away from the center of the hollow quoin, so that the instant the gate moves its tendency will be to swing entirely free from its hollow quoin and thus prevent unnecessary friction.

Many types of anchorage have been used, the main principles to be provided for being strength to sustain the weight of the gate when open, and, more particularly, to avoid any buckling or compression back strain in the anchorage bars when the gate receives its pressure. These points are best secured by using a steel collar bolted to a box which, in turn, is held in firm position by bolts running into the masonry. This box and collar can be so arranged that they may be easily adjusted by placing metal shims between them, and the nuts on the bolts may be so designed that whenever the gate pressure commences against the lock wall there will be no bearing against the bolts; the wall taking up the strain instead of the bolts, thus preventing compression or buckling.

The valves for locks have likewise been the subject of a great deal of study, and nothing has yet been found free from important objections. The "Stoney" sluice and valve, which is composed of a built-up gate hung on counterpoised chains and which runs on a carriage of live rollers, has been used successfully for many years; but it is open to the objection that the leakage is considerable and that in closing the valve the bottom is acted upon by the upward pressures, which prevent prompt closure.

"Butterfly" valves, turning either on vertical or horizontal axes, have been likewise used extensively, and for low heads these seem to give very satisfactory results. The objections to them are that they are difficult to remove in case of accident, that they oppose a large cross-section within the waterway when open, and that they require considerable power for their operation.

The simplest form of valve, and one that has given good satisfaction under moderate heads and for small flow, is the balanced or circular valve introduced into this country by Colonel Merrill, Corps of Engineers, but said to have been invented by a French engineer named Fontaine. These valves have few weak parts, are arranged so that the pressures of the water are balanced in

much the same manner as the piston valve on a steam engine, and are simple and effective; but they are open to the objection that they require a considerable length of vertical shaft for their installation. This excludes them from use as lower valves, unless objectionable bends are used in the culverts.

### *Hales Bar.*

The principal lock and dam in the Tennessee River now under construction is that at Hales Bar. This structure is a pioneer in the policy of constructing works for the combined use of navigation and development of hydro-electric power. This lock has the highest lift designed in this country, and higher than any known to exist abroad. The difference at low water between the elevation of the upper and lower pools will be about 40 feet.

The dam is to be of concrete, and will be 8 feet wide on top, with a bottom width of 64½ feet at the deepest place and an average width of 50.5 per cent of its height. The lock will have 300 feet available length by 60 feet width of opening, and all structures will be founded on solid rock. This work is being constructed under contract with the United States, the only consideration therefor being the privilege of using for the period of ninety-nine years the water power thus made available. At the end of this period the entire construction is to revert to the United States. The profits arising from the sale of hydro-electric power in Chattanooga are expected to compensate the contracting company for the large outlay necessary.

It may be said in general that the Tennessee River lends itself with peculiar facility to improvement by locks and dams, owing to the excellent foundations which may be found throughout its entire length where this method of improvement is practicable, to the stable banks and bottom, and to the comparatively large discharge.

## LATERAL CANALS.

The fourth method of improving navigable rivers, referred to above, is by lateral canals. It has been effectively used for many years, antedating the canalization method. Familiar examples in this country are the "Soo" Canal around the rapids of the St. Marys River, the Cascades Canal around the rapids in the Columbia River, and the Welland Canal from Lake Ontario to Lake Erie, cutting out Niagara Falls. Many others might be cited. On the Tennessee River we have the Muscle Shoals Canal, and we are

now constructing the Colbert Shoals Canal to surmount the Colbert and Bee Tree shoals. In many locations where the width of the river is extreme, where the volume of flow is excessive, where the damages from overflow would be prohibitive, or where suitable foundations for dams can not be found, the method of complete canalization is inapplicable, and lateral canals are used. This method of improvement offers a safe passage for boats, removing them entirely from the open-river channel, and overcomes differences in elevation by means of locks, as in the case of canalized rivers.

Objections to lateral canals are that they often collect drift and sediment, the removal of which necessarily forms a constant source of expense, and that they are frequently difficult of maintenance on account of the necessity of protecting the banks from the wash of passing vessels, and the difficulty of closing the canal sides to leakage.

The necessity of adopting this method of improvement is usually indicated by the locality, the main considerations being those of expense and convenience. Muscle Shoals Canal, on the Tennessee River, originally cost for completion, up to 1890, approximately three million dollars. The project for this work has never been entirely carried out, only the worst shoals having been surmounted. Since it was opened to traffic, eighteen years ago, it has cost approximately one million dollars for maintenance. Canalization at this place would have been much more expensive, and probably wholly impracticable on account of the great length of the dams. The total fall of the Muscle Shoals section of the river is upwards of 134 feet, most of which is overcome by two canals, one three-fourths of a mile long and the other 14 miles long, having in all eleven locks. The construction of these works has been of great value to the city of Chattanooga and has aided incalculably in its development, since it places this town in water communication with the Ohio River during the greater portion of each year.

It seems to be admitted, however, that the number of locks is too great for the present methods of handling river commerce, causing considerable delay; and the bends in the canal present additional difficulties in connection with the handling of large tows. It has recently been proposed by a private corporation to construct three dams across this stretch of the river, each about 40 feet high and provided with a suitable lock; the two-fold object being to develop the water power of this section, which amounts to approxi-

mately 90,000 horsepower at low water, and at the same time to overcome the objection raised to the present canal, by providing better facilities for navigation. The company expects the United States to give them material assistance in the construction of these works, so that the cost of the power development may be correspondingly reduced. This work would involve enormous expense, the dams proposed being of unusual height and their combined length exceeding 3 miles.

Should the United States adopt a new policy in the direction of assisting power companies in cases where their projects are more or less intimately associated with the interests of navigation, an entirely new field of enterprise will be opened, the extent of which can not now be foretold. It seems doubtful, however, whether such a policy will be adopted in the near future.

In the construction of lateral canals many engineering problems arise. The Muscle Shoals Canal, for instance, was compelled to cross a number of small creeks. One of these was passed over by an aqueduct carrying the canal prism, constructed of steel plates and resting on masonry piers. Small streams were permitted to flow into the canal, weirs being placed opposite their mouths to permit the excess flow to pass out of the canal. These streams bring in sediment which must be removed periodically.

At Colbert Shoals the canal, which is 8 miles long, has been constructed partly in the bank and partly in the river bed. In the latter portion one side of the canal consists of a concrete wall 2 miles long.

Nearly all lateral canals are constructed with a guard gate at the upper end to protect the canal from drift and to enable repairs to be made more easily.

### DREDGING.

The fifth method of improvement mentioned above consists of dredging. Dredging is the layman's cure for all river diseases where lack of depth is the diagnosis. It is indispensable in many locations and useful in most places.

Dredging, however, lowers the river bed, which in turn often lowers the water surface. This in its turn frequently reduces the depths on shoals above the locality under improvement, causing trouble at places which were not objectionable before. It will thus be seen that dredging must be done with care and judgment. Where the discharge is comparatively small and the slope comparatively steep, dredging or other excavation of the river bed must be watched

closely to prevent doing more injury than good. It is more particularly where slopes are flat and the discharge comparatively large that dredging finds its most useful application. The improvement, by this means, of the Tennessee River below Riverton has been eminently successful, as here the usual low-water discharge is about 10,000 cubic feet per second and the slope is only about 4 inches to the mile. The increased areas of cross-section due to the dredged channels produce comparatively slight effects on the water surface.

Care should always be taken, however, wherever dredging operations are carried on, to insure the maintenance of the normal section by some contraction elsewhere, if a channel of considerable depth or width is to be excavated. Accordingly, it has been found very desirable to contract the flow of the river to a sufficient extent to compel the currents to assist in maintaining the newly-dredged channel. On the Tennessee River it has been customary, wherever the material dredged is hard enough, to waste it in piles or spurs at suitable places, so that the surface may be maintained and in order, also, in some localities, to regulate inequalities in the slope. A series of gauges, well spaced, is necessary in observing these effects.

Dredged channels in our small rivers should usually be placed near one bank, where pilots will have a means of locating themselves in the improved channel way. Dredged channels should never be dug in curves,but should invariably be laid out in straight reaches, for simplicity in setting ranges and greater ease in navigation. They should, as a rule, follow the concave side of the river, to take advantage of the best currents to keep them free from sediment; spur dikes being placed on the opposite bank, if found necessary. Care should be taken, however, not to diverge more than is necessary from the direction of currents, since wherever natural currents cross artificial cuts deposits will be formed.

# CREOSOTES AND CREOSOTING

*BY*

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The use of creosote for the preservation of timber is daily becoming of more importance as the scarcity and cost of timber increases. There are many methods of treating timber with creosote, all of more or less value according to circumstances, but the one known as the "Bethel dead oil of coal tar process," or the "Pressure process," is of greatest value and is the one generally meant when the term "creosoting" is used.

Other creosoting methods are generally designated by some descriptive words, as "Open tank," "Brush," "Rueping process," etc.

### RUEPING PROCESS.

This last mentioned process is, I believe, named after its inventor. It is recommended for light treatment only, and its value is up to the present time unknown. It should, however, have some value, and experiments now being carried on in various parts of the country, notably by the Santa Fé Railroad Company in connection with the protection of railroad ties, should soon give us data to base conclusions upon. It is described now, because it will be mentioned at times during the following discussion. This process consists of taking seasoned timber, subjecting it to an air pressure of some 40 pounds per square inch, and while the pressure is maintained, allowing the entrance into the tank of the hot creosote and then increasing the pressure to a sufficient degree until the required penetration is obtained. About 15 pounds per cubic foot can be forced into pine in this manner. The creosote is then drawn off and a vacuum is created; the compressed air within the wood cells, acting upon the release of the pressure, drives out most of the oil, so that where 15 pounds per cubic foot may have been injected, after the oil has been driven out by the compressed air it will be found that only from 2 to 5 pounds of oil have remained in the timber.

With timber of small dimensions thorough penetration has been obtained by the above method, and it is claimed that the strength of the timber has been increased rather than diminished, owing perhaps to the fact that the wood cells have received a thin coating of creosote, which, upon drying, may act to strengthen the cell walls. So far as is known, timber treated by this latter method has not been experimented with in marine work, but it is almost certain that it would not resist the teredo. It is doubtful to my mind if the process has very great preservative value when used for timber to be exposed to the elements, because of the porous and spongy condition of the timber after treatment. It is being used by the Santa Fé Railroad Company in the treatment of their ties. Sufficient time, however, has not elapsed since they began its use to show definite results.

Another point unfavorable to this process is that the timber being cold and the oil hot, or at least warm, a portion of the heavy constituents of the oil are crystallized or coagulated and remain in the wood. For this reason, principally, the Santa Fé Railroad uses the German oil, which is deficient in naphthalene and therefore loses less by crystallization than would other oils. After each treatment the oil becomes less and less a preservative for this reason, and besides it is adulterated by the sap, resin, etc., withdrawn from the timber.

"It is argued that inasmuch as the timber is not steamed, the hot oil dissolves and liquefies the natural substances of the wood—i. e., resin, sap, etc.—and in drawing the air and oil out, when the vacuum pump is applied the excess oil is necessarily greatly adulterated, and its preservative qualities impoverished, and after this emulsion is used over and over a few times, while it may have the semblance of creosote, it is no longer a timber preservative. It will be seen that timber treated with an emulsion of creosote, sap, resin, and water, with a great proportion of the preservative qualities of the creosote lost, through evaporation and volatilization, by reason of frequent reheating of the emulsion, will not endure much longer than timber in its green state."

For these reasons plants using this process are liable to have an adulterated oil in their tanks.

### BETHEL PROCESS.

The "Bethel" process is the one of particular interest at the present time in connection with marine construction, and is the one to which the following statements apply unless otherwise indicated.

If proper care is exercised in treating timber by this method, the strength of the fiber of the wood will be practically unimpaired, and the life of same prolonged from fifteen to fifty years, according to the amount and quality of oil injected and the uses to which the timber is put. It is the only commercially practical method by which timber may be protected against the teredo, and the amount required to be injected for this purpose at a given locality has in general depended upon the activity of the teredo at that locality. It has ranged from 8 or 10 pounds per cubic foot for northern waters to 24 pounds for south Atlantic and Gulf waters, the proper requirement for any harbor generally being determined by experience in that harbor or the near vicinity. When heavy treatment is attempted the operation requires judgment and care, and it is owing to lack of such judgment and care that the result oftentimes leaves much to be desired. There seem to be no standard specifications covering the mechanical process among engineers or the firms engaged in this business, and there are no standard specifications in general use for creosote.

Besides the unsatisfactory results which may arise from accident, lack of judgment or ignorance, there are also those from improper treatment intentionally given. A manufacturer who buys the best oil and does, in my opinion, give the timber the best of treatment, says in a published circular:

"Unfortunately for the conscientious manufacturer, there are many in the creosoting business whose sole object is to make as much money as possible, giving as little in return as they dare. In order to save time, and practically double the capacity of the plant, by running two charges through the cylinder in the time necessary to properly treat one, the unscrupulous will subject the charge to excessive steaming, with superheated steam, thereby destroying the fiber of the wood, and in reality defeating the object of creosoting, by destroying the timber instead of preserving same. Others, taking advantage of their customers' ignorance of creosoting, will fail to inject sufficient oil into the wood, relying on the fact that the product, being costly, will not be cut up to ascertain its condition. These are the 'tricks of the trade' which work a hardship on the conscientious manufacturer, who, when requested to bid on certain work, will base his figures on full and proper treatment, whereas some of his competitors may, and in many cases do, not propose to furnish the material according to specifications, thereby securing the business at a lower figure than others can afford to quote, and, as creosoted material all looks alike on the outside, they have no difficulty in passing their inferior products. The fact that many users of creosoted material seem

to think that their advantage lies in 'beating' the manufacturers down in price puts a premium on this practice. If they would ascertain for themselves that the oil used was the best, and then appoint a qualified inspector to see that they received all they were entitled to, both oil and method of treatment, they would be really doing something worth while; for what are a few dollars per M. feet saved in price compared with possibly double the life of the timber when properly treated?''

As a result of the use of oils of different preservative value, and of treatments of varying thoroughness, it is natural that the results should vary greatly, and it is probable that most cases of failure of creosoted timber in marine, or even other work, have been caused by deficiencies of oil or of treatment, or both. The ordinary causes of failure are: insufficient oil; poor oil, either a thin creosote or an adulterated oil; faulty mechanical process, as lack of seasoning, improper steaming, with reference to time or temperature, or both; leaking valves; shortening time of process, or endeavoring to treat unsuitable timber. Most cases are due to insufficient oil, poor oil, or overheating the timber. If the steaming is not sufficient, the oil can not be injected; if the valves leak, the oil is not injected. Well seasoned and fresh green timber can not properly be treated in same charge.

A creosote oil that contains a large proportion of soluble or volatile ingredients (that is, speaking generally, those that distil over at low temperatures) is unsuitable, because those ingredients are soon lost from the timber. Specifications should be adopted that will prevent the use of such creosote or adulterated oils.

Ordinarily, specifications will require the best obtainable creosote oil and the injection of a definite number of pounds per cubic foot. The usual method of determining whether specifications have been followed is to place an inspector at the works to watch operations, and the inspector employed often has little or no knowledge of chemistry and is not sufficiently expert to determine the quality of the oil or the value of the treatment given. It is probable that there have been large quantities of creosoted lumber turned out from various plants under specifications for heavy treatment that have not received anywhere near the specified treatment. Although most engineers have heard such complaints, it is a subject that has been investigated little, and, in my opinion, not sufficient attention has been given by engineers to seeing that their specifications have been complied with in all respects.

OPERATION.

The actual operation of injecting the creosote is divided into three parts: the steaming of the timber to dissolve and evaporate the contents of the wood cells; the application of a vacuum to empty the wood cells by drawing off the sap and resinous substances, and the injection of the creosote under pressure.

For light treatments air seasoning or hot-air seasoning may be substituted for the steaming process, but in general for a treatment of 14 pounds per cubic foot or more the timber is steamed. Besides facilitating the removal of the contents of the wood cells, the steaming, if carried far enough to raise the temperature of the timber throughout above 100° C., sterilizes it and prevents absolutely any deterioration of the timber by rot as long as the outside cells are filled by the antiseptic oil.

As protection against the teredo it is probable that the creosote acts merely mechanically, as it seems the teredo does not bore the wood for food, but rather for a home in which to grow and be protected. Its food is thought to consist wholly of infusoria, which are not obtained from the wood itself. Creosote is to the teredo a disagreeable and possibly poisonous substance in which he will not or can not live. Therefore, where the teredo is active and the waters warm, heavily-treated timber must be used with the object of providing an excess of oil which will during a long period remain within the cellular structure of the timber. The amount of creosote per cubic foot commonly required in the waters of the Gulf of Mexico is 20 to 24 pounds. In Louisiana, Alabama, and Mississippi 20 pounds is the heaviest treatment usually required. Engineers in charge of some of the plants say they can not inject more than that amount without steaming at a higher pressure than 35 pounds. This *may* be correct with reference to some kinds of pine, but I do not believe it is.

On the Texas coast 24 pounds is almost invariably required for pine timber, and the Galveston Wharf Co. is now asking for 27 pounds, or what is practically complete saturation. I have known of several cases where over 26 pounds per cubic foot have been injected. The statement has often been made that it is impossible to thoroughly penetrate long-leaf pine. This statement is not correct. Very recently we had occasion to specify 24-pound treatment for wharf timbers of selected long-leaf heart pine, showing not more than 1 inch of sapwood on one side of any timber. This timber

received 25.3 pounds per cubic foot without any apparent injury to the timber and showed thorough penetration throughout.

The operation of injecting this amount of oil into timber is practically as follows: The timber is run into the treating cylinder; after the doors are closed, live steam is admitted at a pressure generally of from 30 to 45 pounds per square inch and the steaming is carried on from eight to forty hours, the exact time depending upon the individual opinion of the operator, as well as upon the moisture content of the timber, the amount of oil to be injected, the size of the timber under treatment, its hardness and compactness, etc. In some cases the steam pressure is allowed to go above 45 pounds, but there is constant risk of injuring the strength of the timber and the pressure must be watched carefully. By watching the drainage of the cylinders an operator of experience can tell by the color, consistency, etc., of the fluid drained off when the timber is being injured.

Timber that has been steamed at a pressure of over 35 pounds should be under suspicion and the pieces tested by dropping or subjecting them to bending strains to see that the timber is not "cooked." Even when subjected to pressures under 35 pounds damage is sometimes done. The injury seems to be of several kinds; the cell wall may be broken down by expansion due to the creation of steam from the sap and water in the cells or they may be charred by too great heat long continued, or they may be broken down by too long boiling.

When the steam is at last blown out of the cylinder, the vacuum pumps are started and as much of the air, water, sap and resinous substances as possible is exhausted from the cylinder and from the wood structure. The vacuum is usually held for from two to six hours, at from 17 to 26 inches. Finally, the preservative is run into the cylinder while the vacuum is held as far as possible until the timber is covered by oil and the pressure pumps are started and continued until the desired amount of oil is forced into the wood. The amount is generally determined by measurements on the storage tank. Upon completion of the treatment the surplus oil is returned to the storage tanks, the timber is allowed to drip for a few minutes, the cylinder doors are opened, and the treated timber is withdrawn.

The process itself as described appears to be a simple one, but there are many things that may be done or left undone which will affect materially the finished product.

CREOSOTE OIL.

Before proceeding further it will be necessary to discuss the subject of creosote oil.

One of the by-products of the manufacture of coal gas is coal tar, a very important one on account of the numerous and valuable chemicals obtained therefrom, among which are ammonia, carbolic acid, coal-tar dyes, creosote, etc.:

When coal tar is distilled "water passes over holding salts of ammonia in solution and accompanied by a brown, oily, offensive liquid, which collects upon the surface of the water. This is a mixture of the hydrocarbons which are lighter than water, viz., benzine, toluene, xylene, and isocumene. * * * As the distillation proceeds and the temperature rises a yellow oil distils over, which is heavier than water and sinks in the receiver. This oil, commonly called 'dead oil,' is much more abundant than the light oils and amounts to about one-fourth of the weight of the tar and contains those constituents of tar which have a high specific gravity and boiling point, particularly naphthalene, aniline, quinoline and carbolic acid. The proportion of naphthalene in this oil increases with the progress of the distillation, as would be expected from its high boiling point, so that the last portions of the oil which distil over become nearly solid on cooling. When this is the case, the distillation is generally stopped, a black viscuous residue is found in the retort, which constitutes pitch and is employed for the preparation of Brunswick black and asphalt for paving." (Bloxam's Chemistry, page 774.)

This pitch is also used for other purposes, as manufacture of roofing paper, etc. The point at which the distillation ceased will, of course, determine the ingredients of both the pitch and the dead oil.

In America there is practically no market for the hard pitch, but there is a market for the soft pitch for roofing. Therefore, American oils generally will be lighter than the English oils and will contain very little, if any, of the high-boiling oils. English oils, on the other hand, contain a large percentage of the heavier and higher boiling oils.

As a result of the process of its manufacture, creosote contains various chemicals and in varying degrees, depending upon the quality of the tar and the temperature at which the distillation was terminated. After the extraction of the chemicals from this "dead oil," which are commercially valuable, as aniline, carbolic acid, and sometimes napthalene and anthracene, there remains the commercial oil "creosote." It will, therefore, be seen that the oil sold as creo-

sote is that portion of the dead oil of coal tar left over after those hydrocarbons that are commercially valuable are taken out. Mixed with this residue or refuse oil may be other chemicals, which were used in the process of extracting some of the valuable hydrocarbons. If the creosote is obtained from works where the carbolic acid is extracted, the oil will have a low percentage of "tar acids." If naphthalene has been extracted, the oil will be low in that quality, and if roofing pitch has been manufactured, there will be almost no anthracene, because the distillation ceased before the oils containing anthracene were distilled over. Varying as commercial creosote oils do, their preservative value must also vary greatly.

There are also other oils on the market which are mixed with coal-tar creosote or substituted therefor, as crude petroleum, oil from Mondproducer tar, oil-gas tar, etc. There are many opinions as to the value of these oils as preservatives. Chemists do not agree as to the value of the various oils or the ingredients thereof, and engineers therefore are at a loss when making specifications.

At one time it was thought that creosote should have a large percentage of tar acids. A series of experiments by Mr. Coisne, an engineer of the Belgian Government, showed this idea was incorrect.

"He used samples of creosote oil containing 15 per cent, 8 per cent, and 7 per cent of tar acids and one containing no tar acid. He impregnated wood shavings with these oils and placed them in a putrefying pit. After four years in this pit, he found that 'the results were strikingly in favor of the heavier oils and averse to the tar acids, which last bodies appeared to have been wholly ineffective. The shavings which had been prepared with the lightest portion of the oils, although they had contained the largest portions of the tar acids, were, nevertheless, in the worst condition.' * * * Best of all were the shavings prepared with the heaviest oils, produced by distilling at the highest temperature, even when containing no tar acids; these last were all perfectly sound. Uncreosoted shavings were all rotten."*

It has also been thought that naphthalene was the most valuable preservative constituent of creosote. The adherents of the "naphthalene theory" claim that the protection is gained by the volatilization of the lighter oils which disinfect the water that enters the wood, and thereby kill the micro-organisms that would otherwise find a lodging, and that a heavy oil would not do this so readily. They cite the fact that the oil now found in wood well preserved for many years is lacking in light oils (and naphthalene) and contend that the very loss of them is what has protected the timber.

*"Changes in Creosote During Exposure," by Von Schrenk, Fulk, and Kammerer.

Many experiments have been made to determine the truth of this, but the results have not been definite, and it is still a disputed question. Some firms and corporations specify a definite amount of naphthalene, because oils that have been proven successful with them had that amount. It is doubtful, however, if the requirement that there shall be a definite amount of naphthalene in the oil does not result in obtaining a poor oil. It is certain that naphthalene volatilizes easily, and sometimes after only a few days timber impregnated with a creosote rich in naphthalene and protected against air currents will be covered with a white frosting of naphthalene crystals, which when exposed to the elements rapidly disappear. Certainly that portion of this ingredient that crystallizes on the outside of the timber is of no use.

Some people claim that the crystalline naphthalene acts as a stopper in the wood cells to hold the liquid in. I do not believe this, for I have found that oils high in naphthalene dry out of the timbers rapidly, while oils having a large portion of the high-boiling constituents remain in a long time, due to the solidifying of the heavy oil in the outside cells and the deposit of pitch over the surface of the timber.

The analysis of some forty specimens of creosoted timber that had successfully resisted the elements and marine borers for a number of years, made by Prof. Gellert Alleman and published in Circular No. 98, Forest Service, Department of Agriculture, show that of the ingredients remaining in the timber the anthracene and higher boiling oils represented the largest percentage. It is logical that this should be so, because the lower boiling oils are the readiest to volatilize and disappear.

The opinion is becoming more prevalent that the higher boiling oils are the important ones; the "trade" considers as best those creosotes containing the high-boiling oils with a large percentage of anthracene.

The idea that naphthalene is the most important ingredient in the oil has been, however, very prevalent, and that idea has led to the requirement in specifications that a large percentage of naphthalene should be present. Some specifications require as high as 40 per cent.

In a case that has recently come under my observation the oil used was not what is considered by the trade as a first-class creosote oil, and, on objection being made to it, the firm replied that they had to buy that quality of oil in order to comply with certain

specifications, and showed several, some of them Government specifications, that did practically require an oil like the one in question. One case is known where an oil was rejected because it had not sufficient naphthalene. The oil was undoubtedly a poor oil, but should, in my opinion, have been rejected for other reasons. One Government specification at hand allows 25 per cent to be distilled over below 210° C. and does not designate the inferior limit, but, I suppose, 170° C. would be understood. Another specification at hand *requires* 8 to 10 per cent distillate below 200° C., exclusive of water.

In my opinion, that portion of the oil that distils over below 210° C., and certainly below 200° C., is lost from the timber very soon after it is removed from the cylinder and, consequently, to require any proportion of the oil to distil over below 200° C. is to require that just that proportion be furnished in order that same may be immediately lost. The requirements mentioned above could not have been complied with by what is considered as a first-class creosote oil. The best English creosote oils will not comply with those requirements, and in consequence American oils which are deficient in high-boiling constituents or foreign adulterated oils would have to be furnished.

The Forest Service has published Circular No. 112, "The Analysis and Grading of Creosotes," which is of particular interest in this connection, and to which the readers of these remarks are referred for more technical information.

## DISTILLATION.

In most specifications the composition of the oil is specified in one of two ways, viz., by designating the percentage of certain compounds, or by specifying the percentage of distillates, between certain temperatures.

In using this latter method the manner in which the distillation is to be made must always be designated, because analysis of the same oil by different chemists, or even by the same chemists, will show greatly varying results, owing to the different methods and different apparatus employed. To illustrate this point, the following analyses of the same sample by the same chemists are cited:

"The oil was distilled according to two methods: Analysis No. 1, according to the standard method of analysis adopted by the American Railway Engineering and Maintenance of Way Association; Analysis No. 2, according to the English method of analysis as used by Messrs. Burt, Boulton & Haywood.

Analysis No. 1.

| | Per cent. |
|---|---|
| Below 210° C. | 1.6 |
| 210° C. to 235° C. | 18.8 |
| 235 to 270 | 35.9 |
| 270 to 315 | 14.2 |
| 315 to 355 | 17.7 |
| Residue | 10.9 |

Analysis No. 2.

| | Per cent. |
|---|---|
| Below 210° C. | 0.5 |
| 210° C. to 235° C. | 2.3 |
| 235 to 270 | 37.2 |
| 270 to 315 | 21.8 |
| Residue | 38.2 |

It will be noted that the English method of analysis shows a higher percentage of the high-boiling oils than the other method. This must be remembered in studying data relating to creosotes.

## ERRORS.

With reference to ordinary errors that may occur during the chemical process, the following is quoted from Circular No. 80, Forest Service:

"There are three sources of error which are likely to cause material difference in analyses made by different workers.

"1. The accuracy of thermometers, even high-priced ones, is problematical. One of the thermometers used in the experiments reported, the list price of which was $10.00, showed errors ranging from 1.4° at 200° to 6° at 500°. A cheaper, nitrogen-filled thermometer showed a rise in the zero point of 23° after being heated to a high temperateure. When using thermometers for high temperature work it is necessary, therefore, that great care be exercised to insure their accuracy.

"2. The readings of the thermometer are too low on account of the emergent thermometer stem being at a lower temperature than the portion in the vapor. On the thermometers which were used in the experiments detailed above this correction amounts to about 2.3° at 240°, and about 8° at 360°C. No corrections for the emergent thermometer stem have been made, since such corrections are not ordinarily made in creosote analyses. It is probable that the amount of this correction would be nearly the same for the thermometers used by different analysts, so that no great variation in results should come from this source.

"3. It is very essential that a creosote sample be absolutely liquid before the quantity used for distillation is weighed out, since a small amount of unliquified naphthalene will produce an appreciable error in the results of the distillation. It is not at all improbable that the samples sent to the laboratory for analysis may not represent the average composition of the creosote under examination, and this may or may not be under the control of the

analyst, but it is possible for him to obtain a perfectly representative sample of the oil which is brought into the laboratory."

VARYING METHODS IN USE.

Besides the errors mentioned above it has been found that different results are obtained due to the shape and capacity of the vessel used in distilling the oil; the rate at which the distillation takes place; and last, but most important of all, the position of the thermometer bulb, whether in the oil, just above the oil, or just below the outlet tube.

The method common in England is to place the thermometer directly in the oil, generally one-fourth inch or one-eighth inch from the bottom of the flask. In this country it is sometimes specified that the bulb of the thermometer shall be one-fourth or one-half inch above the liquid. To show how important the position of the bulb of the thermometer is, the following tables are copied from a published article entitled, "Standard Method for Analysis of Coal-tar Creosote,"* by Dr. Hermann Von Schrenk, E. B. Fulks and A. L. Kammerer.

TABLE NO. I.—Influence of thermometer position, using the same retort and the same oil.

| Fractions. | Two thermometers in the retort. | | One thermometer in the retort. Bulb ½ inch above oil. |
|---|---|---|---|
| | Bulb in oil. | Bulb at off-take. | |
| Below 210° C. | 1.75 | 82.54 | 11.43 |
| 210° C. to 240° C. | 41.54 | 11.32 | 47.31 |
| 240° C. to 355° C. | 50.37 | | 34.35 |
| Residue | 5.88 | 5.88 | 6.52 |
| Total | 99.74 | 99.74 | 99.61 |

Simultaneous readings of two thermometers.

| Bulb in oil, °C. | Bulb at off-take, °C. | Bulb in oil, °C. | Bulk at off-take, °C. |
|---|---|---|---|
| 210 | 115 | 290 | 201 |
| 210 | 123 | 300 | 206 |
| 218 | 144 | 310 | 208 |
| 222 | 158 | 315 | 208 |
| 234 | 180 | 318 | 210 |
| 240 | 183 | 330 | 225 |
| 250 | 187 | 342 | 231 |
| 260 | 192 | 350 | 240 |
| 270 | 199 | 355 | 248 |

*Bulletin No. 65, July, 1905, American Railway Engineering and Maintenance of Way Association.

TABLE No. II.—Distillation of oil, showing comparative temperatures at which certain fractions distil, with the thermometer bulb in different positions.

Distilled with two thermometers, one in oil and one at outlet of retort, showing simultaneous temperatures.

| Temperature in oil. | Temperature at off-take, °C. | Distillates. |
|---|---|---|
| | | *Per cent.* |
| 210° C. | 118 | 7.47 |
| 235° C. | 169 | 36.65 |
| 355° C. | 218 | 43.93 |
| Residue | | 11.34 |
| Total | | 99.39 |

Distilled with two thermometers, one in the oil and one ⅛-inch above oil, showing simultaneous temperatures.

| Temperature in oil. | Temperature ⅛-inch above, °C. | Distillates. |
|---|---|---|
| | | *Per cent.* |
| 210° C. | 199 | 7.23 |
| 235° C. | 222 | 35.82 |
| 343° C. | 340 | 44.05 |
| Residue | | 12.16 |
| Total | | 99.26 |

TABLE No. III.—The influence of the kind of vessel used is shown in the following table.

One sample of tar oil distilled under similar conditions in different vessels.

| | 250 cc. side neck distilling bulb. | 250 cc. retort. | 500 cc. retort. |
|---|---|---|---|
| 210° C. | 1.30 | 1.36 | 1.75 |
| 210° C. to 240° C. | 50.14 | 48.27 | 41.54 |
| 240° C. to 355° C. | 38.40 | 46.59 | 50.57 |
| Residue | 9.48 | 3.35 | 5.88 |
| Total | 99.32 | 99.57 | 99.74 |

A study of the above tables will show conclusively how necessary it is when indicating an oil by its fractional distillation that the position of the bulb of the thermometer shall be mentoned. Many discrepancies in analyses by different chemists are explained, and the cause of misunderstandings between manufacturer and consumer becomes apparent after considering the above tables. The first point, therefore, to be determined when a report of a fractional distillation is under consideration is the position of the thermometer bulb with respect to the liquid. As it appears from the studies available that the kind of vessel, its size, the rate of distillation and

the position of the thermometer affect the amount of distillate passing over between any two recorded temperatures, it would seem to be desirable to standardize the apparatus and methods of analysis.

As what we must have is a method that will give uniform results, and with the same oil the same results by all reliable chemists, it would seem that the thermometer should register the temperature of the vapors themselves and not of the oil. Placing the bulb of the thermometer in the oil itself is certain to give results which vary greatly, because it will then register the temperature of the oil that directly surrounds the bulb, and not the temperature of the vapors that are passing off, nor even the general temperature of the liquid. If the bulb be placed just above the oil, the temperature recorded will be affected to a less degree by the temperature of the oil, but it still will not necessarily read the temperature of the gases. If it is placed at some distance above the oil, as in the method recommended by Prof. Gellert Alleman in Circular No. 98 of the Forest Service, the temperature recorded by the thermometer will be more nearly that of the gases passing off, and if the same oil is analyzed a number of times with the thermometer as noted, more uniform results will be obtained than by other methods. I must say, furthermore, that the apparatus as described by Professor Alleman in this circular appeals to me as being more exact and more adapted to obtain uniform results than the apparatus ordinarily used.

The only objection known to the use of the side-neck flask is that the liquid "pops" a great deal and often jumps from the bottom of the flask out through the outlet neck, even though the outlet is 6 inches above the liquid. This happened during many of the analyses made by the inspector operating under the United States Engineer Office at Galveston, Texas, until he covered the flask with asbestos from top to bottom. The probable cause of the "popping" is the condensed vapor, which on falling back into the oil is again vaporized almost instantly. It is very much worse when a quantity of water is in the oil.

A uniform rate of distillation should also be specified, otherwise the analysis can be manipulated by forcing or retarding the heat. The high-boiling oils will volatilize at a temperature below their boiling point, just as water evaporates below 100° C., or they will not have opportunity to become completely volatilized at their proper temperature if the flame is forced. A rate of one drop per second was used in the method of analysis reported in Forest Service Circular No. 112, and until some other standard is adopted such rate is reasonable and is recommended.

It is also important to divide the range of temperature into certain divisions, so that the distillates obtained throughout the range of a division will have some definite similarity. Professor Alleman proposes to separate the distillates in a manner somewhat different from that used by other chemists, and his reasons given in the same circular mentioned above seem to me cogent, and his remarks so instructive that the following are quoted:

"When a complex mixture such as creosote is distilled, the various distillates passing over do not volatilize at the exact boiling point of the individual compounds which they contain, and the compounds can not be separated in the pure state except by repeated distillations. If all creosote oils used were similarly constituted, then, by means of a series of analyses, it could readily be determined at what temperatures the various constituents volatilize; but since oils vary greatly in composition, this is not possible; such temperatures as are determined upon for the separation of the various fractions are, in a measure, arbitrary. For instance, if an oil is rich in naphthalene and also contains a certain amount of material distilling below 200° C., some of the naphthalene is liable to volatilize with the lighter oil, and it will have entirely passed over when a temperature of 245° C. is reached. On the other hand, if the oil contains a large amount of the higher boiling constituents, such as anthracene, and also a considerable amount of naphthalene, the latter is frequently not gotten rid of before a temperature of 250° C. is reached. The point at which naphthalene ceases to come off, if it is present, can be determined by allowing a drop of the distillate supposed to contain it to fall on a piece of cold porcelain. If the drop solidifies, the presence of naphthalene is shown.

"In over eight hundred distillations conducted by the writer it was found that 92 per cent of those oils which contained naphthalene gave it off between 205° C. and 245° C., and one of the fractions has consequently been taken between these temperatures.

"After conducting tests on a great many oils, the writer was of the opinion that the most information could be obtained by separating the distillates as follows:

1. To 170° C.
2. 170° C. to 205° C.
3. 205 to 245
4. 245 to 270
5. 270 to 320
6. 320 to 420
7. Residue above 420° C.

"Fraction No. 1 contains the light oil and water. In case much water is present, some of the naphthalene will frequently volatilize with it.

"No. 2 should contain phenol and the cresols (tar acids).

"No. 3 contains naphthalene and the two methylnaphthalenes;

these bodies crystallize out, and by filtration the amount of solid naphthalene can be determined.

"No. 4 contains, among other compounds, dimethylnaphthalenes.

"No. 5 was usually entirely liquid on cooling, and its composition is complex and variable. In case little anthracene oil is present, some of it will be found in this distillate.

"No. 6 usually contains anthracene oil, phenanthrene, acridene, etc., and solidifies on cooling.

"The residue above 420° C. may contain practically the same as No. 6, and also tar.

"'Tar acids' is a technical term used to denote all those creosote constituents which contain hydroxyl groups. The known compounds of this sort occurring in creosote are phenol or carbolic acid; the ortho, meta, and para cresols, usually termed cresylic acids; A and B naphthol, and xylenols."*

While I am not advocating at the present time any particular method of analysis and am not sufficiently versed in the chemistry of creosote to warrant a recommendation, I must say the above method of analysis and distribution of distillate intervals appeals to me. *I do, however, advocate* some standard method for use of the Corps of Engineers, and I think the subject should be taken up and such standard provided.

## SPECIFIC GRAVITY.

Under the present methods employed, the specific gravity of creosote is variously specified for temperatures of 15° C., 38° C., 50° C. and 60° C. As most oils are not completely liquified at 15° C., and some not even at 38° C., the gravity may be taken at any temperature, and then reduced to 15° C., by using the coefficient .0008 for each degree centrigrade the temperature of the oil is found to be above 15° and adding the product to the observed gravity. If the Fahrenheit scale is used, the factor should be .00044.† The objection to referring the specific gravity to 15° C. is that the factor is not constant for all creosotes. At 60° C. almost without exception, all of the fractions are liquid, and the gravity can be determined directly. All things considered it is thought that the specific gravity should be determined at 60° C. If oil at that temperature be compared with water of the same temperature, a more nearly correct specific gravity is determined. Even this is not accurate, because water and oils have different factors of expansion, and there-

*Circular No. 98, Forest Service.

†Authority: Von Schrenk, Fulks and Kammerer.

fore if reduced to a temperature of 15° C. they would not bear exactly the above relation.

The lowest specific gravity for any fraction of a pure creosote seems to be about 1.01 and that for the fraction under 225° C. The lowest for the high fractions is about 1.07. A creosote falling within the limits of the distillation specified for Class A, in Forest Service Circular No. 112, should probably never be lower than 1.04 at 60° C. An oil having a specific gravity as a whole of more than 1.07 should be looked on with suspicion and investigated. Unless it is almost wholly lacking in the low-boiling fractions it possibly has some hard pitch or undistilled coal tar mixed with it.

### PRACTICAL OPERATION AT PLANT.

Having determined by analysis that the oil to be furnished for a given lot of timber is satisfactory, it is important to see it remains so. One of the particular points to be guarded against is the dilution of the oil by the addition of water. As the storage tanks at most plants have open tops and a quantity of water is usually required on top of the oil for fire protection and to prevent evaporation, the oil passing to the treating cylinder may easily carry water with it, particularly as the oil seems to draw down from the center of the tank and sucks the water down the funnel-shaped depression caused by the flow from the bottom of the tank.

Again the oil in the storage tank must be kept heated by steam coils, else the heavier oils will settle to the bottom and become hard and only the light oils and water can be drawn off. If the steam coils leak, water is mixed with the oil. Dilution may also be caused by not cleaning the treating cylinder of condensed steam, saps and resins, obtained from the timber after the steaming and vacuum processes just before allowing the entrance of the oil; leaking of steam pipes in the treating cylinder, etc.; or by using oil that has been previously used in the Rueping process, already described. This process deliberately mixes all of the sap and resinous substances from the wood with the oil. Oil used a few times in this process may become sadly deteriorated and not fit to be used.

### FAIR SAMPLES SHOULD BE OBTAINED.

During the mechanical operation it is important that the inspector make sure that a fair sample of the oil was submitted for chemical analysis, and for this reason he must be able to make at least a rough analysis to ascertain whether the oil is the same previously

analyzed, and, if so, that it has not become diluted. As creosote is a mixture of various oils having different specific gravities, and if stored in a tank whose contents have not been stirred and particularly if unheated, the oils gradually arrange themselves more or less in layers according to specific gravity. The heavier oils at the bottom become hard, and if a portion of the oil from such a tank is drawn off it is very likely that only the lighter oils and water will be withdrawn. For this reason the oil when about to be used should be kept heated to about 80° C. In taking samples from a tank having considerable vertical height a vessel should be used which will enable the inspector to take his sample at any height, and samples from the bottom, middle and top of the tank should be compared, and even while the injection is taking place samples should also be tested that are drawn from the treating cylinder, because at every step of the process, and at every movement of the oil, dilution may take place.

### STEAMING.

When steam is applied, there is a rapid condensation in the cylinder, due to the cooling action of the cylinder and wood. To prevent this, some plants use superheated steam sufficient to absorb this condensed water; or rather to prevent the condensation. After the condensation ceases, the timber gradually becomes heated and the sap is volatilized from the wood, as are a large part of the resinous compounds, sufficient steam being let into the cylinder to replace the lost heat and take up the additional moisture. If the timber is green and contains a large amount of sap, the cylinder is sometimes blown out several times during the steaming. By far the larger part of the sap constituent of the wood is extracted during the steaming process and passes off as steam and water through valves in the bottom of the cylinder.

The degree of heat necessary to be used is that which is sufficient to volatilize the sap and resinous substances. The more sap in the wood the higher the pressure that can be safely used. For heavy treatment, a pressure of 20 or even 25 pounds may be insufficient to effect the desired result. I believe the best results are obtained by using 30 to 35 pounds pressure. Forty pounds may be needed for green timber, provided it is live steam. Superheated steam should never be used even at low pressures, except at the very beginning, when the timber and cylinder are cold. One creosote company allows a pressure of 60 pounds on all their work, irrespective of the

required treatment. They claim to have steamed paving blocks as high as 80 pounds without causing deterioration sufficient to be detected, even under such a test as heavy traffic gives them. They evidently do not damage the timber or they would have modified the treatment. None of the other plants that I am acquainted with is able to use such heavy pressures, and I have grave doubts about the reliability of the recording instruments. The greatest damage is caused by burning or rupture of the cell walls, due to superheated steam or to applying the pressure too fast. If the material is heated slowly, there is not such great danger of rupturing the cell walls. A dry timber should not be steamed at as heavy pressure as a green timber.

According to experience of the United States Engineer Office at Galveston, the best results are obtained by increasing the pressure slowly, taking an hour or two to attain the maximum pressure and then gradually decreasing it.

### THE VACUUM.

The action of the vacuum is perhaps the least understood of the processes connected with creosoting. It is understood, of course, that a certain amount of moisture will be withdrawn, including the dissolved resins, etc., but it is not generally known that most of the moisture is drawn off in a gaseous form and that better results are obtained when the heat is kept up so that the moisture content of the cells may be boiled out under the decreased pressure.

Mr. C. M. Davis, United States inspector under the Galveston office, reported as follows:

"The vacuum seems to volatilize the moisture left in the wood after the steaming process is completed, if the timber is kept heated. At Slidell, La., we obtained the best results by having steam in the cylinder coils while the vacuum was on. The vacuum seems to cause the water in the wood to 'boil' and vaporize very rapidly, and this vapor passed out through the vacuum pump. Some was, of course, left in the cylinder and was collected in the 'sap cylinder' underneath the treating cylinder, but the amount thus collected was surprisingly small. In the case of a charge of 2,000 cubic feet of very green pine—so full of sap that it would not float in water—there was less than 1 pound per cubic foot collected in this manner out of, possibly, 25 pounds per cubic foot extracted."

### INJECTION OF OIL.

The vacuum is generally used to accelerate the filling of the treating cylinder with oil. It is very important to have the cylinder filled as quickly as possible, in order that absorption may be as

uniform as possible. By proper management of plant the cylinder may be filled in about ten minutes without pumping, but when the arrangement is poor and pumping has to be resorted to it may take an hour or more.

At most plants the method used to calculate the amount of oil to be injected is to measure the timber and find the amount required to be injected measured in tenths of a foot on the tank gauge. The oil is turned into the cylinder, and a gauge reading is taken when the overflow pipe from the cylinder shows it to be full. Then the number of tenths from the tank is injected by pressure less the amount of absorption which must be estimated, but which is eventually checked by a final reading of the tank gauge after the surplus oil is returned to the tank. This method is open to the objection that there is no way of determining whether the estimated amount of absorption was correct or not until the process is ended. A better method is to use the cubical contents of the cylinder, the displacement of the load and the amount to be injected. With these data the uncertain quantity, absorption, is disregarded.

A close inspection of the process of injecting the oil should be made. Improper steaming and vacuum processes show for themselves in the finished product, but a deficiency of oil can not be determined without expensive investigation. Every source of supply of oil should be gauged before and after treatment. It is not unusual to have connections from the cylinder to several supply tanks and to one or more outlet tanks from which the oil is finally returned to the supply tank. No valve is free from the tendency to leak even under the best of management. Especially important is the correction to be made for change in temperature of the oil in the storage tank before and after treatment. Creosote oil changes in volume approximately 1 per cent for every 12½° C. A thermometer should be attached to the side of the supply tank in such a position that it will not be locally affected by the steam coils, and readings taken before and after the operations and the gauge readings corrected for the change in temperature. It is not uncommon for this to make a difference of as much as 4 or 5 per cent in the number of pounds injected.

### ABSORPTION.

The amount of oil absorbed before pressure is applied depends on the time taken to fill the cylinder, the grain of the timber, the extent of seasoning and steaming and the viscosity of the oil. It never

seems to be uniform even under seemingly the same conditions.

In the case of the two treatments illustrated by Fig. 1, the loblolly stock absorbed 27½ per cent during the fifteen minutes taken to fill the tank. The long-leaf timber absorbed 23 per cent in twelve minutes. The two charges were seasoned to about the same extent, and the absorption was the greatest and the most uniform I have noted, viz., about 6 pounds per cubic foot in each case.

Such high percentages of absorption as this can only be obtained by using a very hot oil and having the timber thoroughly steamed, possibly oversteamed. In these cases the oil was kept at a temperature of 88° C. Generally the absorption is much less, and when the oil is applied at low temperatures, as 50° C. to 65° C., the absorption may not amount to more than 10 per cent.

Only such oil as is practically free from tar acids should be applied as hot as 88° C., as it is thought that the tar acids affect the structure of the wood materially if the temperature of the oil is too high during injection.

In the case of light treatments too great rapidity of absorption is a serious drawback to uniform treatment of the charge. The timber at the bottom of the cylinder absorbs so much more than those at the top that it becomes very noticeable, particularly if a long time is consumed in filling the cylinder. When only the amount of oil is supplied to provide an average treatment for the charge, and the timber is seasoned, the oil hot, and if a long time is employed in filling the cylinder, the bottom timbers may have double the requisite amount and the top timbers practically none.

### RATE OF INJECTION AND PRESSURE.

The accompanying curve (Fig. 1) shows the relative rapidity with which the oil was injected into two charges of timber under contract with the Galveston Engineer Office. In the case of the long-leaf pine the percentage of heartwood was about 25. The sapwood was entirely penetrated in five hours, and evidently a large part was penetrated in about two hours, as shown by the abrupt break in the absorption and pressure curves. The curves illustrate what may be called average cases, and they show the importance of having all of the timber in a single charge of the same density. More especially is this the case with light treatments, for reasons mentioned above.

When different woods are combined in a charge, the less dense get more than was intended and the close grained less than was

intended. Cases have been noted where long leaf and loblolly pines were included in the same charge, with the result that the loblolly were saturated and the long leaf received only 3 or 4 pounds per cubic foot and only 1 or 1½-inch penetration.

### EXAMPLES FROM EXPERIENCE.

A description of a recent experience, in attempting to obtain a good treatment, may be of interest to others.

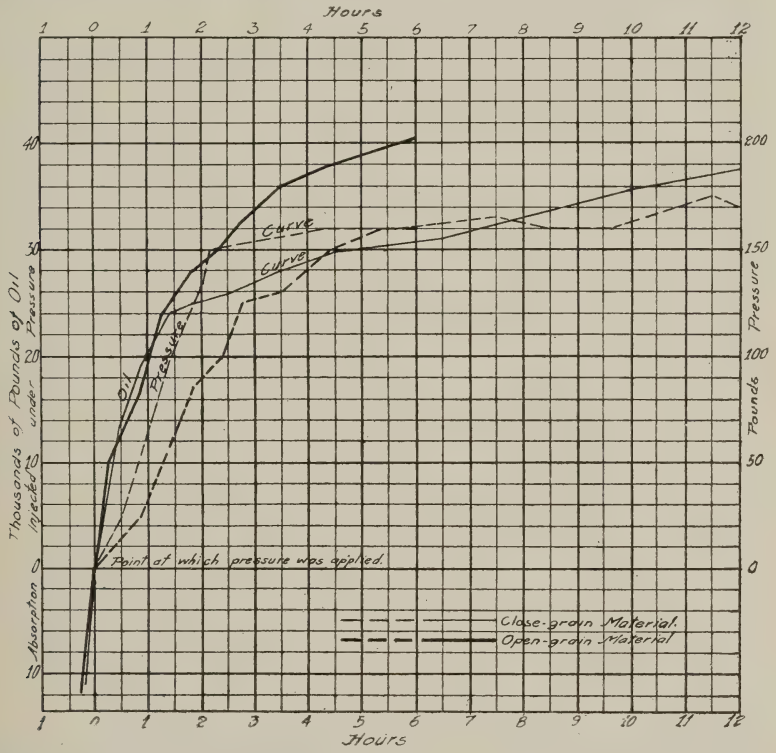



Fig. 1. Curves showing rapidity with which oil is injected into different classes of timber.

The specifications for creosoted piles called for 24 pounds per cubic foot, the use of a good creosote oil, that the strength of the piles should not be impaired and that they should be protected against the teredo. Realizing that it would be difficult to make specifications that would be fair to both contractor and Government, no effort was made to specify the kind of oil to be used or treatment to be given other than the above, but an affidavit was required

of the president or manager of the company that the specifications had been complied with. Upon delivery of the piles their appearance was noted as peculiar, the penetration was found to be slight, and although the affidavit of the manager of the company stated that 24 pounds per cubic foot had been injected, upon submitting samples to two chemists, one sample was reported to have 4.8 pounds per cubic foot and another sample, which was one of the best penetrated of the piles, contained only 10 pounds per cubic foot. The analyses also determined that the oil was inferior. Judging from the samples taken, it became apparent that the piles did not contain the necessary amount of oil, notwithstanding the records of the company showed the treatment and the amount of oil received by each charge as being sufficient to supply an average of 24 pounds per cubic foot in the timber treated.

The question as to whether the oil was too light and diluted with water or was lost through some carelessness, leaks, open valves, or whether the reports from subordinates of the company were incorrect, is still to a certain extent an open one. Whatever the causes, the fact remains that the piles did not receive the amount of good creosote oil specified. If they did receive the required weight of the mixture furnished as creosote, the oil was so volatile that more than 50 per cent of it disappeared during the course of from three to six months' exposure. This last supposition can not be accepted, for reasons that to my mind are conclusive, and I was forced to decide that the treatment was deficient.

The company desired to furnish other piles to replace those rejected and wanted to use the same oil which had been reported on adversely by the chemist employed by the Government, still claiming that the oil was "a good oil." To illustrate the difficulty of determining whether it was a good oil or not, the following is submitted:

"Analyses made by chemist of 'Wholesale Dealer:'

| | |
|---|---|
| Specific gravity | 1.033 |
| | *Per cent.* |
| ___° C. to 170° C. | .7 |
| 170 to 210 | .5 |
| 210 to 235 | 24.3 |
| 235 to 270 | 40.0 |
| Over 315° C. | 18.2 |
| | 99.9 |
| Naphthalene | 23.5 |
| Tar acids phenols | 7.5 |

(Apparatus not indicated. Position of bulb of thermometer not known.)

"The presence of considerable amount of tar acids indicates origin of this oil from coal tar."

"Analysis by chemist of 'Creosoting Company:'

Specific gravity at 35° C. ..... 1.03

Distillates.

| | Per cent. |
|---|---|
| 0° C. to 170° C. | .5 |
| 170 to 210 | 6.5 |
| 210 to 240 | 50.5 |
| 240 to 350 | 26.0 |
| Residue above 350° C. | 16.0 |
| | 99.5 |

(Position of thermometer bulb not known. Apparatus not indicated.)

Samples of two piles from the same lot and supposed to be from the same charge and impregnated with the oil in question were forwarded to two chemists of national reputation in this line. The piles had been exposed to atmospheric conditions about six months.

"Report of first chemist on Sample A:

Distillates.

| | Per cent. |
|---|---|
| 1. ___° C. to 170° C. | ----- |
| 2. 170 to 205 | ----- |
| 3. 205 to 245 | 21.27 |
| 4. 245 to 270 | 16.49 |
| 5. 270 to 320 | 18.41 |
| 6. 320 to 420 | 21.18 |
| 7. Above 420 | 22.31 |
| | 99.66 |

"From distillate No. 3, 11.06 per cent solid naphthalene was recovered. All other distillates were liquid on cooling, proving the absence of anthracene oil.

"Amount of anhydrous oil per cubic foot of timber, 4.79 pounds. (Should have had 24 pounds.)

"The entire absence of anthracene oil in the higher fractions, together with the peculiar appearance of the latter, indicates that the oil used was not a straight creosote oil or dead oil of coal tar.

"A mixture of creosote oil rich in naphthalene, together with a heavy oil from water gas tar or a heavy oil from water gas tar to which sludge naphthalene had been added, would form a mixture similar to this oil."

Thermometer bulb at outlet tube of distilling flask, and not touching the oil.

"Report of second chemist on Sample A:

| | Per cent. |
|---|---|
| Below 210° C. | 0.5 |
| 210° C. to 235° C. | 2.3 |
| 235 to 270 | 37.2 |
| 270 to 315 | 21.8 |
| Residue | 38.2 |

"Amount of oil in pile, 3 pounds per cubic foot.

"The oil is a pure product of coal-tar distillation and *as now* in the pile is a high-grade quality of coal-tar creosote.

"We estimate the loss during exposure approximates 40 per cent to 50 per cent."

After correspondence this chemist acknowledged that he did not consider the oil as originally injected as a good oil, but after the water and light oils had evaporated it was a good oil.

"Report of first chemist on Sample B:

Distillates.

| | Per cent by weight. |
|---|---|
| ---° C. to 170° C. | ------ |
| 170 to 205 | ------ |
| 205 to 245 | 28.32 |
| 245 to 270 | 21.71 |
| 270 to 320 | 9.04 |
| 320 to 420 | 17.79 |
| Residue | 22.93 |
| | 99.79 |

"From distillate No. 3, 21.49 per cent solid naphthalene was recovered. No anthracene oil present.

"This sample had 10.04 pounds per cubic foot."

Same method as for sample A by first chemist.

No report was received from second chemist on Sample B.

Attention is invited to Figs. 2 and 3 as showing differences, according to various reports.

The question at once arises as to how to explain the divergence of these various analyses. It will be noted that the analyses of the wholesale dealer and the company using the oil, taken from samples before there was much possibility of the oil becoming diluted or adulterated, agree fairly well, and such divergence as is shown may be readily explained by the fact that the samples were taken from different parts of the storage tank and possibly different methods

of analysis used. This oil was an American oil, very thin, and rich in naphthalene. It was, in my opinion, a very poor oil to start with, and further investigation discovered that the chemical constituents varied very greatly from the bottom of the tank towards the top; particularly later, when the oil became diluted with water and possibly with other materials, there was a great difference between the sample taken from near the top and another from near the bottom.

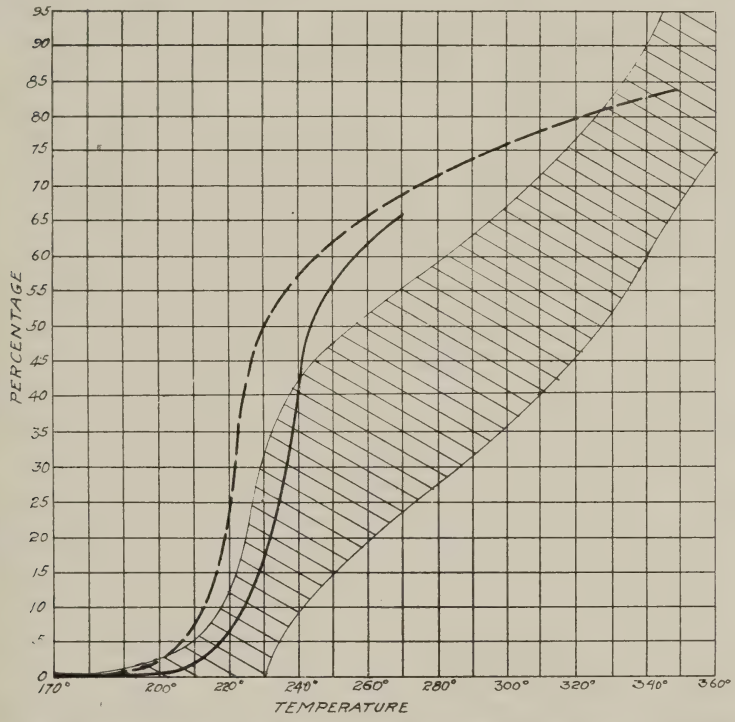



Fig. 2. Curves showing the divergence of analyses of the same oil by different chemists, also comparison with the limits of Grade "A" recommended by the Forest Service. *Full line,* analysis furnished by wholesale company. *Broken line,* analysis made for treating company.

Furthermore, this oil was brought to the plant in a tank steamer that had been carrying crude petroleum, and it is possible that some crude petroleum had been left in the tank of the steamer. There is no telling how much there was left, but our analyses show that it is probable that the oil was mixed with petroleum in this way. When this oil was pumped into the storage tank, there was some German oil in the bottom of the tanks.

When we come to the analyses of the oil taken from the samples of piles in question, it will be seen that the analyses by the same chemist of the two different samples vary greatly. The different amount absorbed during treatment, owing to different positions in the charge, may account partly for this, and the varying specific gravities of the ingredients of the mixture may account for part. There was much water in the oil, probably at least 15 per cent, much very light oil and, of course, some heavy oil.

When a mixture like this enters the treating cylinder, it is natural that the heavy oil should settle very rapidly to the bottom and the lighter oil and water to the top. Because of this and the difference in absorption that may take place, the piles of the same charge would receive different amounts and also oils of different specific gravity. Consequently it is not difficult to explain the discrepancy in the quantities of the distillates of oil from the two samples, if we assume a great length of time for filling tank and a very poor oil used that was mixed with water and perhaps other oils or saps. An examination of the piles leads to the conclusion that such assumption is correct.

When we compare, however, the analyses of the oils extracted from the Sample No. 1 by two different chemists, a remarkable difference is shown. One chemist found 3 pounds per cubic foot and the other 4.79 pounds per cubic foot. This again might be explained in part by the fact that, of course, one sample was nearer the end of the pile than the other. As the sample sent each chemist was 3 feet long, if one part was very near the end a considerable difference in the amount of oil injected might be found. But no explanation occurs to me to account for the discrepancy in the amount of the distillates or in the final conclusions by the two chemists, except that chemists are not yet able to obtain accurate results by the methods in use.

The chemist who found 4.75 pounds per cubic foot did not know the name of the creosoting company using this oil nor did he know, unless by surmise, that there was any conflict between the parties to the contract. The second chemist furnished said analysis for the creosoting company and was aware of the conflict between the parties to the contract and was hired and paid by the contracting company. If it were not for the fact that the chemist in question is a man of national reputation, it would almost look as if he had allowed himself to be affected by his retainer; but I can not believe that this is the case, and we must look for the explanation in the

different methods and apparatus used and to the fact that knowledge of the constituents and their proportions in creosote oils, as compared with those derived from other oils or other methods, is not at all accurate and seems to be limited.

Again, what are we to think of an oil that is reduced 40 per cent to 50 per cent by volatilization during from three or six months? The fact that the piles were almost as dry as seasoned timber after three months, and could be handled without soiling the hands, leads to the conclusion that the oil was undoubtedly a very poor oil, con-

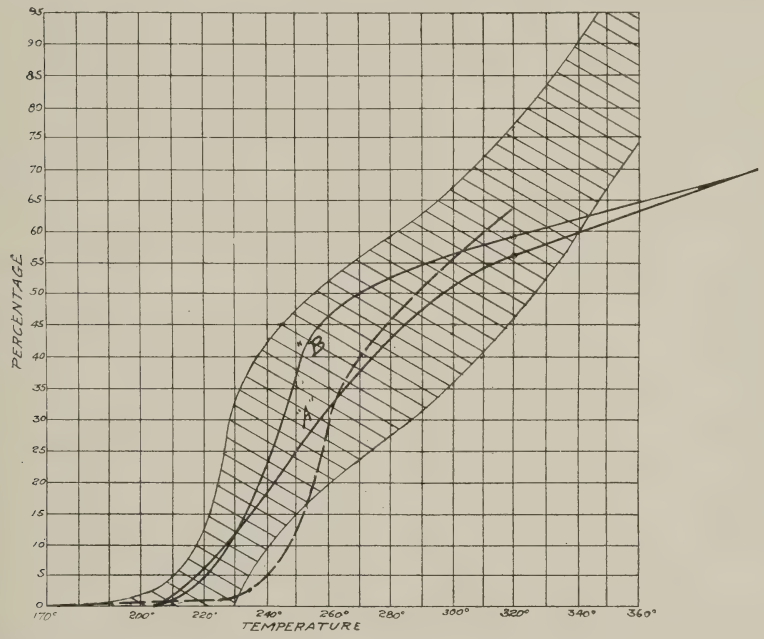



Fig. 3. Curves showing analyses by different chemists of the same oil as in Fig. 1 after three months' exposure in the pile. Comparison with the limits of Grade "A" as recommended by the Forest Service. *Full line "A,"* analysis made for United States Engineer. *Broken line,* analysis of oil from the same pile made for treating company. *Full line "B,"* analysis made for United States Engineer of oil from another pile of the same lot by the same chemist as "A."

taining a large proportion of water and probably some crude petroleum, some sap and resin and a large proportion of low-boiling oils. But it is impossible for me to believe that 40 per cent to 50 per cent of true creosote oil, even with a large percentage of water, evaporated in that time. It will, however, be noted that there was

no distillate below 200° C. found in the timber by either chemist. This would seem to show again that only the high-boiling oils are valuable.

The piles in question having been rejected, the question of oil was again taken up with the company. A sample of the oil proposed to be used when analyzed showed:

"Thermometer bulb at mouth of outlet tube.

| Distillates. | *Per cent by Weight.* |
|---|---|
| 1. ___° C. to 170° C. | 0.85 |
| 2. 170 to 205 | 6.59 |
| 3. 205 to 245 | 53.99 |
| 4. 245 to 270 | 13.05 |
| 5. 270 to 320 | 12.74 |
| 6. 320 to 360 | 8.23 |
| 7. Residue above 360° C. | 4.95 |
| | 100.40 |

"Small amount of pitch. Specific gravity, 1.038 at 15° C.

"Water, 0.38 per cent.

"41.46 per cent of solid naphthalene recovered from distillate No. 3.

"One-fourth of No. 5 and whole of No. 6 solidified on cooling on account of anthracene present.

"Oil contains no impurities; fairly good quality."

This sample was taken by an employee of the creosoting company from the storage tank, evidently from the bottom; and there is a suspicion that the sample may have lost some water and low-boiling oils before being analyzed. At any rate, it evidently was not a fair sample, because after the oil had been brought to the operating plant, put in the storage tanks there and run through the various pipes, etc., a sample of this oil, taken by a Government inspector, was sealed and sent to the Department of Forestry for analysis, with the following result:

"Thermometer bulb same as above.

Specific gravity, 1.0230 at 50° C.

| | |
|---|---|
| Water content | 12.7 |

| Distillates. | *Per cent.* |
|---|---|
| 1. ___° C. to 170° C. | 5.5 |
| 2. 170 to 205 | 9.7 |
| 3. 205 to 255 | 44.3 |
| 4. 255 to 295 | 11.1 |
| 5. 295 to 305 | 2.9 |
| 6. 305 to above | 13.3 |
| 7. Loss gas, etc. | .5 |
| | 100.0 |

"Sulphonative residue of 7.8 per cent was found in fraction 285 to 295. This residue had a very low index of refraction, and its gravity was much lighter than water. The low physical constants and the sulphonation residue places this oil in Grade D. The water content is, however, too high to admit of even this grading. It is probably a mixture obtained by the distillation of the coal and oil tars."

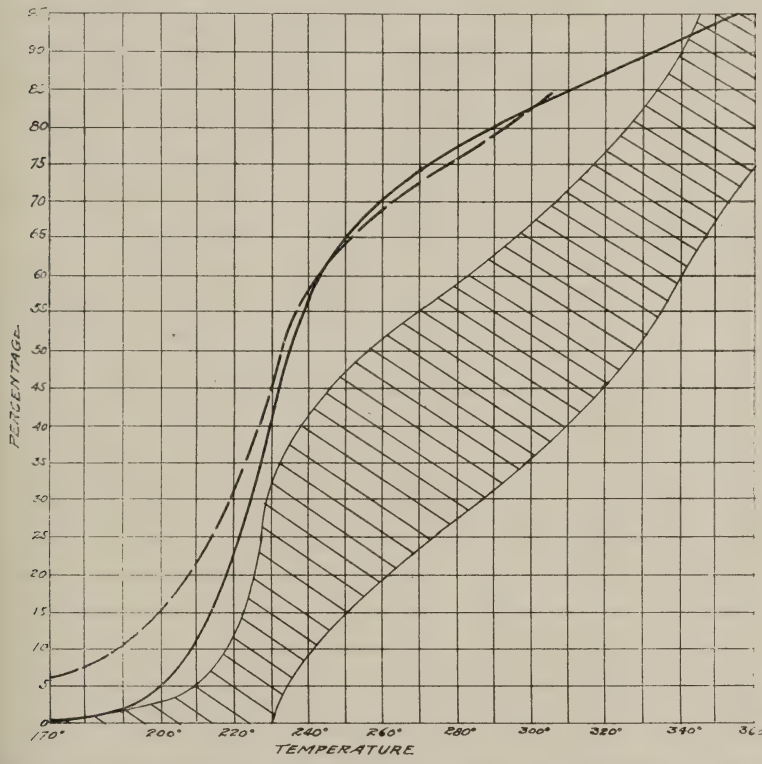



Fig. 4. Curves showing divergence of analyses of samples taken from the same oil. Comparison with the limits of Grade "A" as recommended by the Forest Service, same method. *Full line,* sample taken from storage tank before use. *Broken line,* sample taken from cylinder during treatment.

Attention is invited to Fig. 4, as showing graphically the divergence of these analyses.

While waiting for the above analysis, the United States inspector at the plant took one sample from the storage tanks on the dock from which the sample sent to the Forest Service was supposed to have been taken, and one from the supply tanks at the plant after

the oil was transferred from the dock to the plant. These samples were analyzed for water and oils distilling off below 170° C. with the following results:

"Sample from tanks on wharf:

| | *Per cent.* |
|---|---|
| Showed water | 8.66 |
| Oil distilling off below 170° C. | 3.66 |
| Total | 12.32 |

"Sample from supply tank at works:

| | *Per cent.* |
|---|---|
| Water | 21.20 |
| Oil distilling off below 170° C. | 6.30 |
| Total | 27.50 |

The oil was rejected, as they were unable to free the oil of water.

Here again we find a vast discrepancy shown by the analyses. There is no doubt that the samples were taken from a supply of oil pumped into the storage tanks at one time from one vessel, and the only way to account for the discrepancies is that the first sample taken by the company was taken from the bottom of the storage tank after the oil had been undisturbed for a long time and had had time to arrange itself in layers according to the specific gravity of the various ingredients. The Government inspector stated that the oil at the bottom of these tanks before warming was practically solid. The light oils and a quantity of water which was mixed with the oil, or was possibly on top of the oil, was carried to the operating plant and was there evidently mixed with oil, water, sap and resin in the pipes and the tanks at the plant.

From the above experience it is very evident that the oil question is a very serious one. First: To determine the kind of oil required. Second: To see that an oil that complies with the specifications is used. In my opinion, the oil to be specified, where heavy charges for marine work are required, should be a heavy, high-boiling oil, with a very small percentage distilling over below 210° C., and with practically no water therein. If an oil could be obtained with no oils distilling below 210° C., I would specify such, but I believe that is impossible at the present time unless a special oil is prepared for a particular job. When an oil is specified, the greatest care on the part of the inspector at the works will be necessary to make sure that such an oil is being used. The samples taken for

analyses should be taken from different parts of the tank and their contents averaged, or the samples should be taken from different parts and mixed before the analysis is made. Even then you can not be sure that the oil that is actually being used has not received water or other adulterants between the time the oil is analyzed and used, and the inspector should be competent to make analyses while the work is being performed, taking the oil from the side of the treating cylinder while the work is actually being done and the oil is being forced into the piles.

The tabulated list (page 142) shows different treatments given to timber during the past six months for construction works under my charge, with two additional cases that came directly under my close observation. It will be noted that there is no uniformity of practice, the treatment varying materially at each plant.

CONCLUSIONS.

For marine work and heavy treatment of 20 or more pounds per cubic foot of timber.

*Oil.*

Should be best English coal-tar creosote oil or its equal without admixture of other oils or substances not derived from the distillation of coal-tar; its relative gravity at 60° C. compared to water at the same temperature should not be less than 1.04; it should contain not more than 3 per cent water, the percentage to be compensated for in computing amount of oil to be injected; not more than 5 per cent should distil below 210° C. and not more than 25 per cent below 235° C., when analysis is made by Forest Service method (see Circular No. 112); not more than 5 per cent tar acids should be allowed in oil; oil should be at same temperature in tanks when measurements are made before and after the operation, or shrinkage due to change of temperature should be allowed for; oil should be kept hot during treatment, temperature 80° C. recommended. Allowance should also be made in computations for expansion of treating cylinder under pressure.

*Fair Samples for Analysis.*

Oil should be completely liquid when sample is taken, and if drawn from tanks a number of samples at different heights should be taken and averaged. If taken while oil is being transferred, a drip sample taken from cock in line is desirable.

*Dilution.*

Inspector should watch closely all means of dilution, and make

## *Report of Treatments and Comparison of Results.*

| Plant. | Nature. | Material. | Steaming. | | Vacuum. | | Oil. | | | Total time. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hours. | Max. press. | Hrs. | Inches | Hrs. | Max. pressure. | Temp. | Hours. | |
| | *Lbs.* | | | *Lbs.* | | | | *Lbs.* | °*F.* | | |
| Santa Fe-Somerville | 24 | Green loblolly | 3<br>14<br>15 | 45<br>40<br>35 | 2 | 21–24 | 4-8 | 175–200 | | 38-42 | Piling for Bolivar wharf; average treatment; penetration thorough; timber slightly burned. |
| Do. | 24 | Partly seasoned loblolly. | 14<br>15 | 40<br>35 | 2 | 21–24 | 4-8 | 175–200 | | 35-39 | Do. |
| Do. | 24 | Seasoned loblolly. | 20 | 35 | 2 | 21–24 | 4-8 | 175–200 | | 26-30 | Do. |
| Beaumont | 24 | Green shortleaf and loblolly. | 28 | 47 | 3 | 21½ | 32 | 175 | 183 | 63 | Piling for U.S. immigration service, Galveston; penetration thorough; excellent. |
| Do. | 24 | ----do. | 36 | 52 | 4 | 22½ | 14 | 185 | 184 | 54 | Do. |
| Do. | 24 | ----do. | 32 | 48 | 3½ | 22 | 36 | 190 | 181 | 69½ | Do. |
| Galveston | 24 | Loblolly | 20–24 | | 2 | | 4-8 | | | 26-34 | Usual record from this plant. |
| Do. | 22 | ----do. | 15 | | 2 | 19 | 4-8 | | | 21-25 | For bathhouse; Galveston; penetration thorough. |
| Do. | 14 | Dry loblolly | 5½ | 30 | 1 | 17 | ½ | 40 | 135 | 7 | For U. S. Engineers, Galveston, penetration 3 inches. |
| ——— Co. | 24 | Long leaf and short leaf—green. | 8 | 30 | 4 | 26 | 5 | 150 | | 17 | For U. S. Engineers; penetration 1 to 2½ inches; analyses 6 months later showed 3 to 10 pounds; rejected. |
| Do. | 24 | ----do. | 10 | 40 | 4 | 26 | 2 | 140 | | 16 | Do. |
| Do. | 24 | ----do. | 10 | 40 | 3 | 26 | 10½ | 150 | | 23½ | Do. |
| Do. | 24 | Seasoned short leaf. | 15½ | 42 | 5 | 24 | 7⅔ | 170 | 128 | 28 | Piling for U. S. Engineers; accepted; fair; almost thorough penetration. |
| Do. | 24 | Green long leaf | 24 | 35 | 5 | 24 | 10 | 160 | 130 | 39 | Do. |
| Do. | 24 | ----do. | 26 | 45 | 5½ | 24 | 12 | 150 | 130 | 43½ | Piling for U. S. Engineers; penetration 3 inches; rejected. |
| Slidell | 24 | Green loblolly | 23 | 60 | 6 | 21½ | 7⅓ | 168 | 190 | 37½ | Piling for U. S. Engineers; excellent; thorough penetration. |
| Do. | 24 | Long leaf and short leaf—green. | 24 | 60 | 4 | 25½ | 12⅓ | 175 | 190 | 40⅓ | Piling for U. S. Engineers; excellent; thorough penetration; actual injection 25.1 pounds. |
| Do. | 24 | ----do. | 24 | 60 | 5½ | 25 | 6 | 160 | 194 | 35½ | Piling for U. S. Engineers; excellent; thorough penetration; actual injection 27.0 pounds. |
| Galveston | 24 | Green long leaf heart, 4′ by 10″. | 19 | 45 | 35/60 | 20 | 10 | 110 | | 29 35/60 | Material for U. S. Immigration Service, Galveston; penetration thorough; excellent; actual injection 25.3 pounds. |

sure none has occurred by analyses of oil taken from treating cylinder during process of injection.

*Charge.*

Should be uniform as to kind, cross-section, density and moisture content.

*Steaming.*

Duration and intensity of steaming should be left to management of plant on account of varying equipment at different plants, varying density, etc., of timber from different localities; however, specifications should provide that treatment shall not injure fiber of timber, nor impair strength appreciably.

*Vacuum.*

Same as for steaming, with the additional requirement that cylinder and contents should be kept hot during process by steam coils in cylinder.

*Absorption.*

To do good work a plant should be properly equipped for filling treating cylinder quickly to avoid different degrees of absorption, which tends to overload some of the charge while the remainder does not receive the required amount.

*Pressure.*

Should be continued until gauges show that a little more than the computed amount of oil is injected to allow for dripping and release of oil while cylinder is being emptied of the surplus oil and for the expansion of the cylinder under pressure. The cylinder doors should be opened promptly and the charge withdrawn as soon as possible.

*Inspection.*

Specifications should contain clause requiring management of plant to furnish the inspector every facility requested by him for measuring timber, oil, tanks, cylinders, etc., and for taking and analyzing oil samples as often as deemed necessary, including use of laboratory and such apparatus as he may require.

*Inspector.*

Should have sufficient knowledge of the chemistry of creosotes and the skill to make the necesssary analyses, and should study the

plant carefully to prevent mixing of water, bad oil, etc., left in pipes, tanks, cylinders, etc.

For light treatment the same considerations should govern as for heavy treatment, except that the oil need not be heated to 80° C., the water content may be allowed as high as 8 per cent, all to be compensated for, and more care must be exercised to obtain uniform absorption in order to obtain uniform results.

I desire to acknowledge indebtedness for information obtained from the various publications of the Forest Service relating to this subject, and also for the valuable articles with discussions published by the American Railway Engineering and Maintenance of Way Association, and to other available literature bearing upon the subject.

I am also indebted for valuable assistance to Mr. C. M. Davis, United States inspector under the Galveston Engineer Office, who was present at the plants during the creosoting of the timber supplied under contract with that office during the past six months.

# BREAKWATERS AT MANITOWOC HARBOR

*BY*

IRVING L. GILL
*Inspector*

On May 7, 1907, the United States entered into contract with the Great Lakes Dredge & Dock Company to build a portion of the new harbor at Manitowoc, Wis. The old harbor consisted of parallel piers extending into the lake from the river mouth, the entrance being protected by a breakwater 800 feet long.

The new harbor, designed by Maj. W. V. Judson, Corps of Engineers, is formed by two breakwater arms 425 feet apart at their outer ends, diverging toward the shore and connected therewith by pile piers and rubble mounds, the latter capped with concrete blocks. The plan further provided for the removal of the greater part of the old piers and of the outer 500 feet of the breakwater.

The portion of the old breakwater to be removed, and the outer 500 feet of the south pier, 1,000 linear feet in all, consisted of substantial wooden cribs in good condition and of satisfactory design, each 100 feet long, 24 feet wide, 22½ feet deep, built of pine and hemlock, and filled and riprapped with stone.

The provisions of the contract left it optional with the Great Lakes Dredge & Dock Company to use these ten cribs in the breakwater or to build new ones. For each 100-foot crib complete in the work the United States was to pay $12,000. It was realized that the moving of the cribs would be a hazardous and difficult undertaking. The risk was placed upon the contracting company, because its agents would select the time and methods of doing the work in detail and would thus control, so far as they could be controlled, the risks that would be run. It was well understood that a crib stripped of riprap and emptied of stone to the extent required for transfer would be in grave peril if subject to a heavy sea.

During the summer of 1907 seven cribs were moved. Of these, the first five were satisfactorily placed and completed in the new work. The last two, which were resunk during November, 1907,

were not sufficiently secured before a severe southeast storm arose and wrecked them. They were replaced by the contracting company, so that the United States sustained no loss thereby.

The large sum per crib received by the company doubtless indemnified it for costs, including the losses above mentioned, and still leaves a reasonable profit on the undertaking.

The removal of so many cribs, each of such great size and weight, under the hazardous conditions obtaining in the open waters of Lake Michigan, constitutes an interesting operation, which it is proposed to describe.

The method employed in raising and sinking the cribs was as follows:

Two wooden scows of dimensions shown on Sheet 2 herewith were spaced 26 feet apart; these supported thirteen beams, each consisting of a pair of 24-inch 80-pound I-beams, 60 feet long, and arranged approximately as shown on the drawing. Each member of a pair was held in position with respect to the other as shown in "detail of eye-bolt," Sheet 2; 12 by 12 inch blocking was employed to support the beams. The scows with the I-beams thus arranged constituted a lifting machine. When astride a crib and sunk to a determined depth, it was in position for lifting the crib.

Passing down through each pair of I-beams on each side of the crib was an eye-bolt threaded at the top. An iron washer fitted over the threaded end above the I-beams, and a nut held the load. Leading down from these eye-bolts were 1⅝-inch chains, which in turn were connected to large built-up hooks, on the jaws of which the load was carried. (See "cross-section," Sheet 2.) The hooks with the chains and eye-bolts attached were always placed and fastened on the crib under supervision of a diver, and the scows were then brought into position.

For sinking, the scows were provided with 6-inch valves as seacocks, four being in the longer one and six in the other. During this operation all hatches were battened down. It is evident that the lower the depth of the apparatus the higher it could lift the load. A limit was reached when the I-beams came in contact with the top course of the crib. (See Fig. 1.) In order to arrive at a level sufficiently low to obtain the desired height of lift, the I-beams were blocked up and the crib superstructure cut down.

Part of the blocking was secured by means of 1½-inch tie-rods, running down through the I-beams and the decks into a 12 by 12

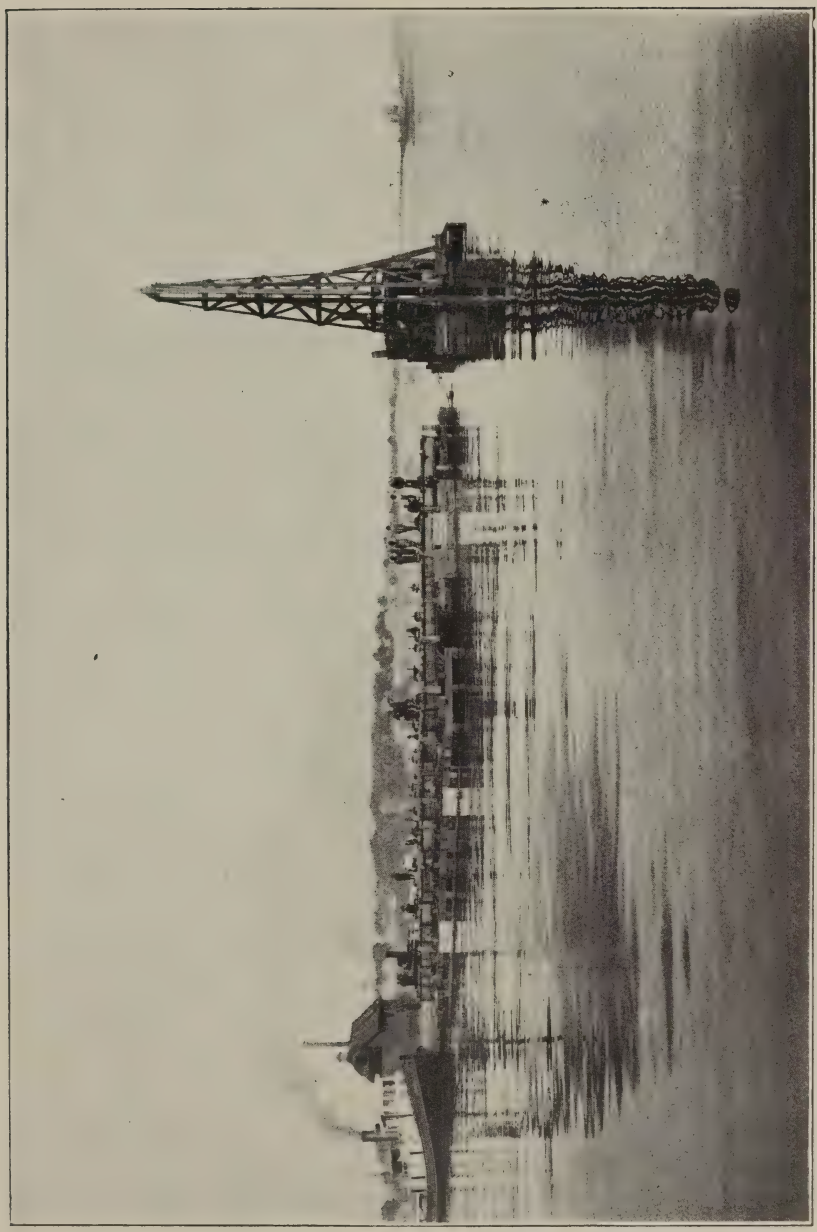


Fig. 1. Scows sunk at each side of crib and ready to be pumped out.

inch timber. All that held the rest in place was the weight of the I-beams. On one occasion this proved insufficient. The scows were being lowered into position and were down to the decks when, owing to the swell on the lake, one end washed under, and much of the blocking was displaced, some floating out. The progress of the work was thus delayed for nearly three hours at a critical period. The stone filling in the crib had been largely removed to lighten the load, and all of the riprap taken away to permit the placing of the hooks. Had a sea suddenly come up the danger of wreckage would have been great. Considering the risk involved and the value of time, it would seem advisable to secure all blocking.

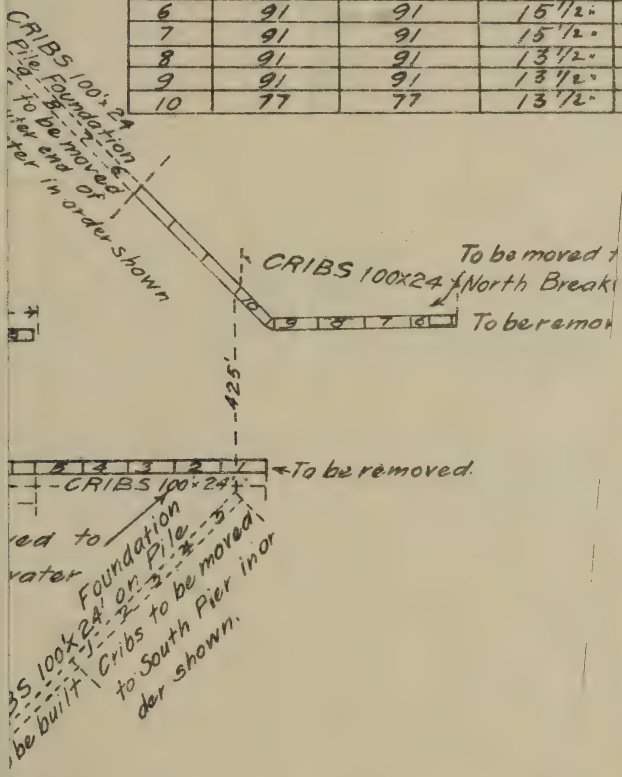
As soon as the required depth was reached, the valves were closed and the chains and rods put in tension by screwing up the nuts. The tension in the various chains was equalized as nearly as could practically be ascertained. A diver was sent down to see that the hooks were securely placed and brought to a proper bearing.

The scows were then pumped out and, floating up, brought with them the crib. Access for air to provide against a vacuum as the water left was furnished by four 3-inch iron pipes, two leading into each hold at the ends. Two centrifugal pumps were used, one an 8-inch and the other a 10-inch, furnished by the Morris Machine Works, of Baldwinsville, N. Y. Steam was supplied by a tug and a pile driver. As soon as the crib was raised high enough to float it over its new pile foundation, it was towed into position (see fig. 2) and lined up; the tug, winches on the pile driver, and lines to other cribs being utilized to accomplish this end. The valves in the scows were then opened and the crib lowered to place. (See Fig. 3.) Care was taken that the contact end settled last, for otherwise an opening between the new and the old work would have resulted. As soon as in plumb, the crib was filled with stone and riprapped.

In the case of the new south breakwater there was no old work to abut against, necessitating a different plan to be followed in placing the first crib. Four breast lines and one stern line were run to large anchors, the slack being taken up partly by winches on the pile driver, which had been made fast to the crib, and partly by blocks and tackles. A dredge was anchored by her spuds on the windward side to give lee, and the pressure of two tugs was used to offset the force of the wind. The crib was forced ahead when necessary by cables run to the winch on the dredge. Little trouble was experienced in the sinking.

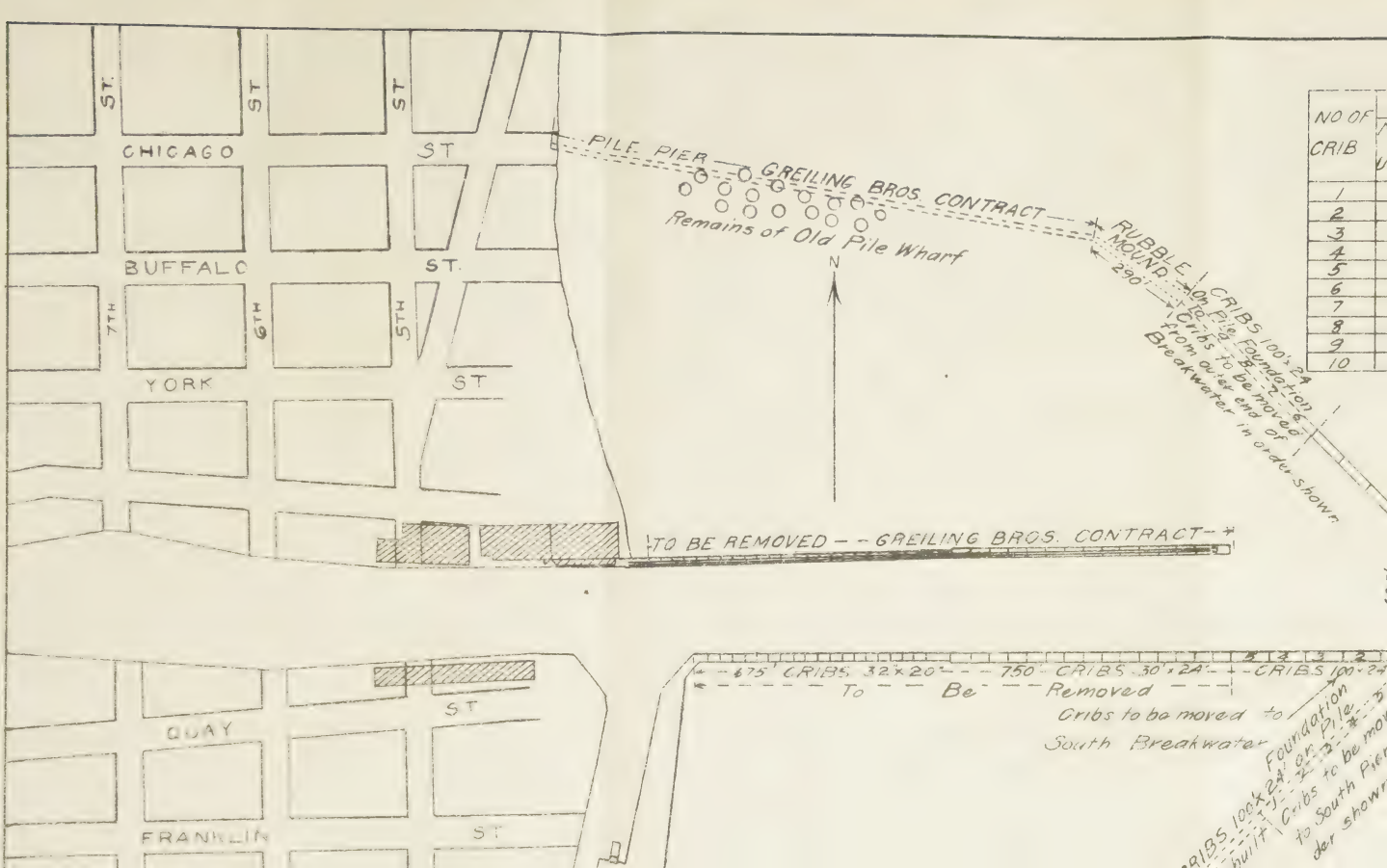
# CRIBS TO BE MOVED

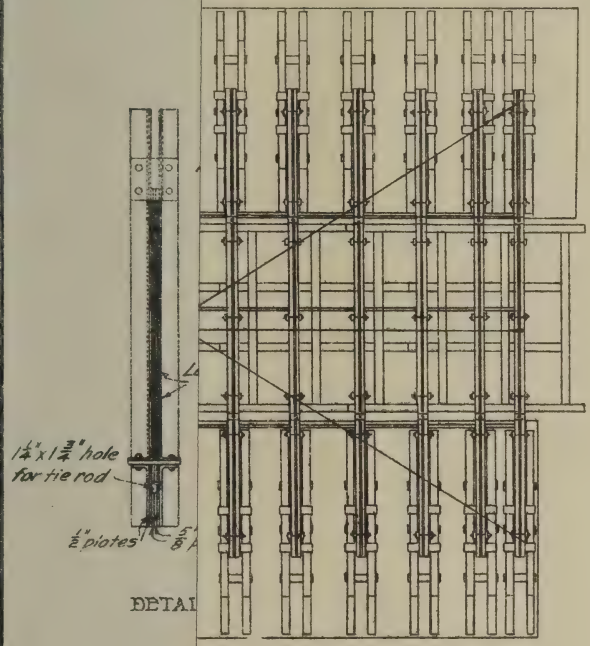
| NO OF CRIB | FOUNDATION PILES | | | NU |
|---|---|---|---|---|
| | NUMBER NOW UNDER CRIB | NEW WORK | | CO SU |
| | | NUMBER TO BE DRIVEN | CUT OFF BELOW DATUM. | TO |
| 1 | 74 | 70 | 15 1/2 Ft | |
| 2 | 69 | 70 | 15 1/2 " | |
| 3 | 62 | 63 | 15 1/2 " | |
| 4 | 62 | 63 | 15 1/2 " | |
| 5 | 62 | 63 | 15 1/2 " | |
| 6 | 91 | 91 | 15 1/2 " | |
| 7 | 91 | 91 | 15 1/2 " | |
| 8 | 91 | 91 | 13 1/2 " | |
| 9 | 91 | 91 | 13 1/2 " | |
| 10 | 77 | 77 | 13 1/2 " | |

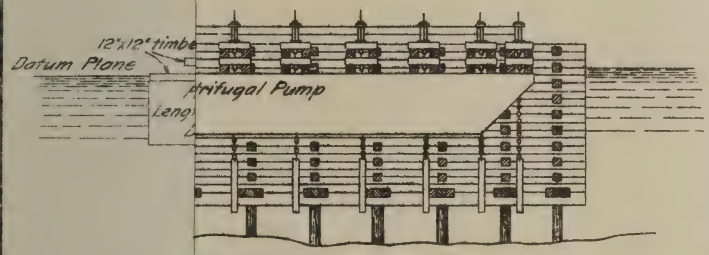



# ARBOR WIS.

1000

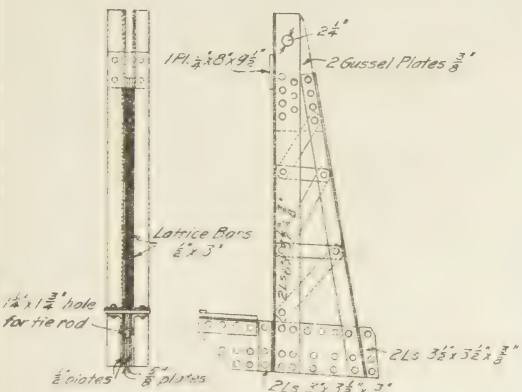

ST.
ST.
ST.
CHICAGO
ST
BUFFALO
ST.
7TH
6TH
5TH
YORK
ST
PILE PIER
GREILING BROS. CONTRACT
RUBBLE MOUND
290'
Remains of Old Pile Wharf
N
Cribs to be moved from outer end of Breakwater in order shown
TO BE REMOVED -- GREILING BROS. CONTRACT
NO OF CRIB
1
2
3
4
5
6
7
8
9
10
QUAY
ST
FRANKLIN
ST
675' CRIBS 32'x20'
750' CRIBS 30'x24'
CRIBS 100'x24'
To Be Removed
Cribs to be moved to South Breakwater
Foundation
Pile
Cribs to be moved to South Pier
der shown



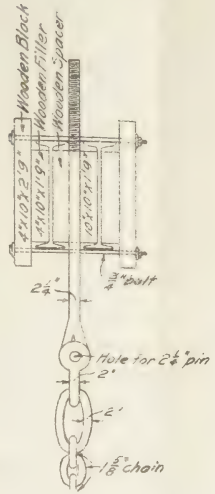




VATION

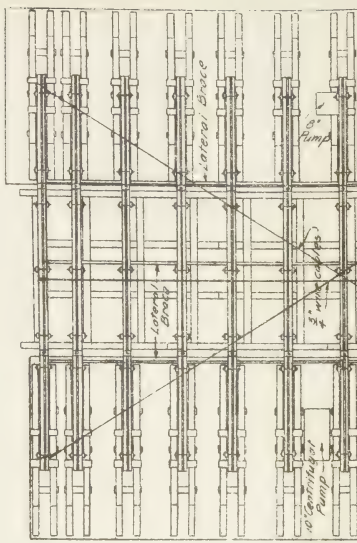
AN
D OF RAISING CRIBS
at Lakes Dredge & Dock Co.
bor, Wisconsin.




DETAIL OF LIFTING HOOK.




DETAIL OF EYE BOLT


Lateral Braces
8" Pump
Lateral Braces
Lateral Braces
Lateral Braces

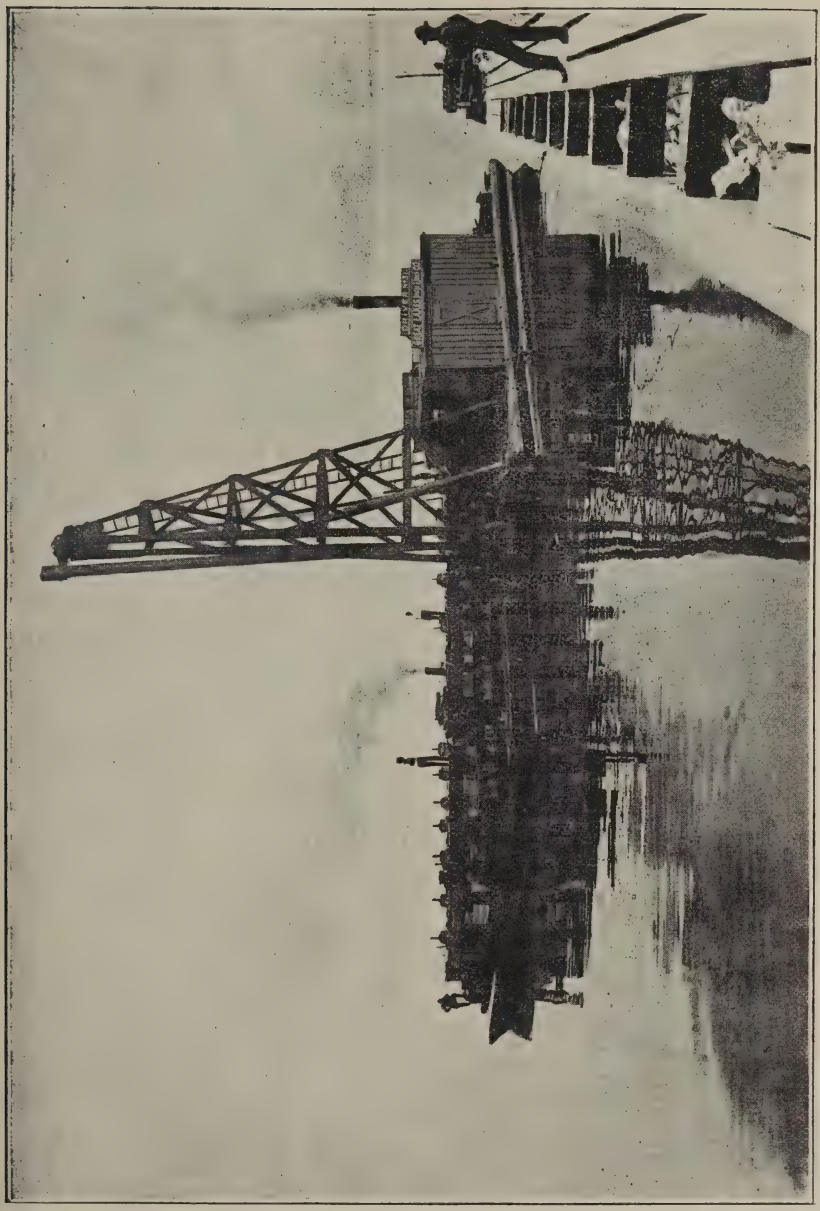


Fig. 2. Crib floated and en route to its new foundation.

The following data are of practical interest:

Number of men employed, exclusive of tug and dredge crews, 25 to 30.

Average time required to sink the scows, 1½ hours.

Average time required to pump out the scows, 1½ hours (very approximate).

Originally each of the four outer cribs of the north breakwater contained about 1,638 tons of stone weighed in air, or approximately 1,200 tons as it stood in the breakwater, part of it being submerged. The stone filling rested on 12 by 12 inch longitudinal floor timbers, which in turn were supported by sets of 12 by 12 inch cross-ties dovetailed into the wall timbers. A set of cross-ties consisted of three pieces of 12 by 12 inch timbers side by side. (See "side elevation," Sheet 2.) The side pieces were of pine and the center piece of hemlock. Since the strength of a structure is equal only to the strength of its weakest part, the safe fiber stress of this set of cross-ties was equal to the safe fiber stress of the hemlock piece. The danger of their shearing off at the walls or of their shearing through the bottom wall timbers was less than that of their failing as beams. The distance from side to side of the crib (22 feet) was the clear span of the ties.

In the first crib moved 420 tons of stone (immersed weight in water) were lifted, the rest having been removed. The interior consisted of thirty-six pockets running lengthwise in rows of twelve. The side pockets contained more stone than the center pockets between them, so that the load coming on one set of three cross-ties may be considered, for purposes of computation, as uniformly distributed over each third of the span, 8.65 tons on the middle and 13 tons on each of the extremities.

Considering these beams as fixed at the ends the maximum bending moment occurred at the walls, and if all the weight from the stone had been imposed on the bottom ties, would have been approximately 1,440,530 inch pounds. This would have caused an extreme fiber stress of about 1,870 pounds per square inch. If the beams be considered as simply supported, this fiber stress would have been a maximum at the center and equal to about 2,340 pounds per square inch. The safe fiber stress for the hemlock piece is approximately 600 pounds per square inch, using a factor of safety of 6. The above computed stresses do not take account of any arching action of the stone, which must have been considerable, nor of the fact that the load was supported partially by the upper

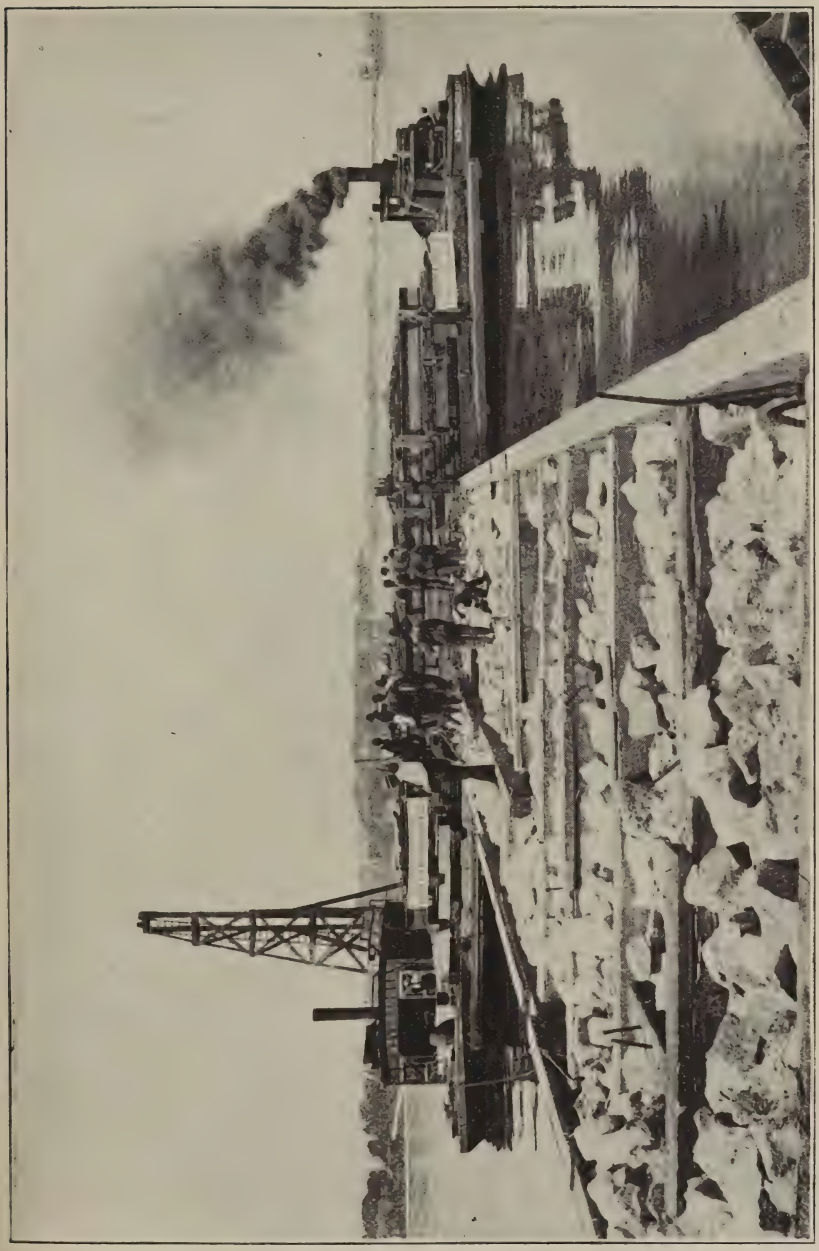


Fig. 3. Sinking the crib in its new position.

cross-ties and longitudinals, and partially by friction with the side walls. These considerations would indicate that the strain on the bottom ties was not excessive.

As to the I-beams, the load coming on them from the first crib moved (and this contained more stone than any other when lifted) is estimated as follows:

| | Tons. |
|---|---|
| Weight of stone in the crib | 420 |
| Weight of crib, including driftbolts | 65 |
| Weight of chains, hooks, etc. | 12 |
| Total superimposed load | 497 |

In the case of cribs subsequently raised, the estimated load was compared with the load obtained by measurements of scow displacements and checked fairly well. Of the above 497 tons, the portion coming on one pair of I-beams, assuming even distribution, was 41.42 tons, or two concentrated loads of 10.35 tons on each I-beam, each situated 12 feet from a point of support. The span being 49 feet, the concentrated loads were 25 feet apart and symmetrically placed relative to the center of the beam. The dead load was 3,920 pounds, uniformly distributed. The maximum bending moment occurred at the center of the beam and was equal to 3,268,000 inch pounds, causing a maximum fiber stress of 18,800 pounds per square inch. The safe unit stress is only about 16,000 pounds per square inch, so that it would appear the load was excessive.

In this connection it may be said that on raising the first crib at least two pairs of I-beams buckled very perceptibly. The nuts over these were immediately slacked off and the strains thus relieved. After the crib was settled in place and the load thus removed, the buckled beams straightened out of themselves, showing that the elastic limit had not been greatly exceeded. In this case there was probably an uneven distribution of the load between the I-beams, resulting from a failure to put the rods and chains in approximately equal tension before lifting.

Another influence effecting the buckling was the lack of lateral bracing afforded. In order to prevent undue strain in compression flanges considered as columns, beams should be braced laterally at intervals not to exceed twenty times the total flange width. Each flange of a pair of I-beams was 7 inches wide, making 14 inches the total flange width of the two I-beams, and 20 by 14 inches, or 23 feet 4 inches, as the minimum allowable distance between braces.

This distance for the first crib was 27 feet 0 inches. An additional set of braces was thereafter used.

In order to avoid the shifting of the scows with reference to one another, and hence the shifting of the I-beams on the blocks, three-fourth-inch wire cables were tied diagonally across and on top of and running transversely over the I-beams. (See "plan," Sheet 2.)

The load coming on the threads of the 2¼-inch eye-bolt running up through each pair of I-beams was approximately 41,420 pounds. The breaking strength of this eye-bolt was 112,000 pounds, making the factor of safety about 2.7.

The chains used were 1⅝ inches in diameter, with an ultimate strength of 123,514 pounds. The load carried was 41,420 pounds, giving a factor of safety of about 3.

The lifting hooks were built up of structural steel, were about 6 feet 9 inches high, and well designed to carry any load likely to come on them. A vertical line through the point of application of the load on the jaw of the hook and the line of resistance to the load through the chain did not coincide, and, on account of the resulting couple, the upper part of the hook was forced over against the crib wall. To remedy this, the rivets in the lug at the top of the hook were countersunk. In order to make the supporting surface of the jaw as nearly horizontal as possible when lifting, it was built at an angle of 87° 4′ with the main tension member.

Openings 1¼ by 1¾ inches were left through the lower part of the hooks (see "detail of lifting hook," Sheet 2) for the tie-rods, and were connected by ⅞-inch wire cables under the crib. The object of these ties was to guard against the lower wall timber being torn off. They were used under the first four cribs moved, but were subsequently omitted as unnecessary.

The above computed strains coming on the various parts were figured for the weight of the first crib moved. Subsequent cribs raised were lighter, more stone having been removed to prevent a repetition of the buckling above described.

In the first four cribs moved the pockets were 6 feet 8 inches wide in the clear, with timber bottoms. In the others the side pockets had no bottoms and were 4 feet 6 inches wide, as compared with a width of 11 feet for the center ones. From the large pockets men loaded the stone on wooden skips, which were then hoisted to a scow and later dumped in the crib after it was placed. As soon as the stone had been removed to about 1 foot below the

water surface a ¾ yard orange-peel bucket was used. This was swung from a 63-foot boom on a derrick scow 132 by 34 by 9 feet, the boom being situated at about the center of the deck. With the orange peel, an average of about 196 cubic feet of stone filling was removed per hour.

Two methods were employed for emptying the open side pockets, which were too narrow to permit of using the bucket. A deep trench was dredged on both sides of the crib for the purpose of allowing the stone from the side pockets to fall through and be dredged up. The stone arched in them, however, and the method proved slow and expensive. On the remaining work divers were employed, who loaded iron skips, which were raised by the use of a portable derrick and dumped on a scow. One diver removed about 50 cubic feet of stone filling per hour, and four divers could be used to advantage at a time. If any stone proved too large for a diver to handle, a chain was let down, made fast, and hoisted out by the derrick. On the whole, this method proved more economical than the first.

The condition of sea and weather has much to do with the rate of progress of the work. There should be no swell when a crib is raised or sunk, and after the contractor is ready to do either he may be delayed indefinitely before favorable conditions are at hand.

# THE GREAT PYRAMID

*BY*

COLONEL D. W. LOCKWOOD,
*Corps of Engineers*

This vast structure appears to have earned its distinction as one of the "Seven wonders of the World," on account of the magnitude of the engineering operations connected with its construction.

The original base side length was between 763 and 764 feet, and the height about 486 feet.

The area of the base was originally about 13.4 acres.

It is quite generally conceded that when completed the exterior of the structure was formed of four equally inclined plane triangular surfaces meeting at the apex.

Whether any opening was left at the time connecting with the interior is of no special interest in this discussion; it may be stated, however, that about 800 A. D. the Caliph Al Mamoun tunneled into the masonry from the middle point of the north side of the base, and thus opened communication with the passages and chambers of the interior. It does not seem at all probable that this work would have been undertaken had the mouth of the Descending Passage been exposed, which became the case when the exterior casing was removed about the year 1000 A. D.

From the mass of literature that has been published concerning the Pyramid, the following conclusions are drawn, which it is believed are practically accepted by the best authorities:

1. It was built as a right pyramid with a square base.

2. Its sides were oriented, running north, south, east, and west. In 1864 Prof. Piazzi Smyth, Astronomer Royal of Scotland, determined the error in orientation to be about 4′ 35″.

3. It was located or designed to be located on the 30th parallel of north latitude. In 1864 Professor Smyth determined its latitude to be N. 29° 58′ 51″, or 1′ 9″ south of the 30th parallel. The savants who accompanied Napoleon in his invasion of Egypt in 1799-1800

made its latitude considerably greater or located it still nearer the 30th parallel than did Professor Smyth.

Without discussing the question as to whether its latitude has or has not changed since construction, it is submitted that under the conditions as they exist, it is permissible to discuss the proposition of a right pyramid with a square base on the 30th parallel of north latitude.

Many years ago the writer was told by Dr. J. D. Buck, of Cincinnati, Ohio, that the location of the Great Pyramid, as above stated, was an important feature in connection with it. So far as known no specifications of the work are in existence; fragmentary references, to be sure, are to be found in certain ancient writings, but these are not complete in any sense, and besides are generally complicated by the introduction of blind and misleading conditions which can only be eliminated when the proper key is known.

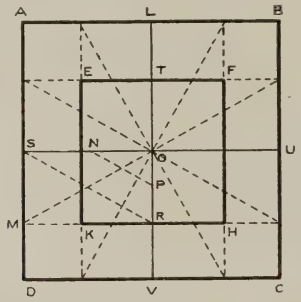



Fig. 1.

Since the removal of the casing, there is, of course, no way of determining what the original height of the structure was, except upon the theory of some definite relation between the height and base side, which relation must, of course, be an assumed one, to stand or fall on its merits.

After a careful study of the many theories that have been advanced by different authorities, I have been forced to conclude that whatever information in a general way the Great Pyramid has to give must be through *suggestion,* and in this connection its location on the parallel of 30° north latitude, and the structure as it stands, are practically about all the data concerning which there is little or no ground for dispute.

1. As to location:

*a.* The sine of 30° equals ½.

*b.* In any sphere whose radius is R, the diameter of a circle 30°

from a great circle is $R\sqrt{3}$, the cubic diagonal of $R^3$, the diameter of a sphere circumscribing $R^3$.

2. The pyramid as it stands with its sides oriented:

*a*. The volume of a pyramid is equal to one-third of the area of its base by its altitude.

*b*. In a pyramid with a square base, this gives rise to two squares, their areas being to each other as 3 to 1, and their sides as $\sqrt{3}$ to 1, or the same relation that exists between the diameter of a circle of 30° of a sphere and the radius.

*c*. If two squares be constructed whose areas are to each other as 3 to 1, with a common center, and their sides parallel, they will constitute a square zodiac.

Let ABCD be a square of any dimensions. (Fig. 1.) Through

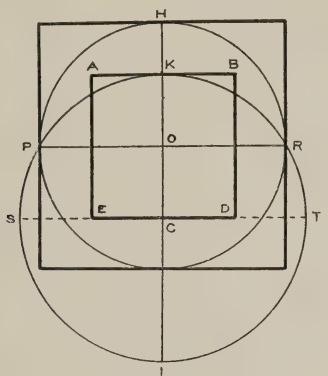



Fig. 2.

the center O draw the lines LV and SU, dividing the large square into four equal squares. With P as a center and PN equal to 2 PO as a radius, describe an arc, cutting SU at N, draw NP. Through S draw SR parallel to NP. Construct the square EFHK, its sides being equal to 2 OR, and parallel to the sides of the larger square. In the right-angle triangle SOR, since SR equals 2 OR by construction, if OR be assumed as ½, SO becomes $\frac{\sqrt{3}}{2}$, whence it appears that if the side EF is unity, the side AB becomes $\sqrt{3}$, and the areas of the two squares are as 1 to 3.

If, now, the sides of the square EFHK be prolonged to intersect the sides of the outer square, and these points of intersection be joined with O, a square zodiac will result, since each of the 12 angles about O is equal to 30°.

It would appear that the 30th parallel, the Pyramid and the zodiac are intimately related geometrically.

The relation 1 to $\sqrt{3}$, between the radius of a sphere and the diameter of the 30th parallel, suggests a cube circumscribed by a sphere.

In Fig. 2 let ABDE be the face of a cube; through its central point O draw the lines HI and PR at right angles to AB and AE, respectively. With C as a center and CK as a radius describe a circle; then PR will be the diameter of the 30th parallel of the sphere whose radius is CK. With O as a center and OP as a radius describe a circle, and circumscribe it by a square whose sides are parallel to the sides of the square ABDE.

A pyramid base is now complete, equipped with a square zodiac as

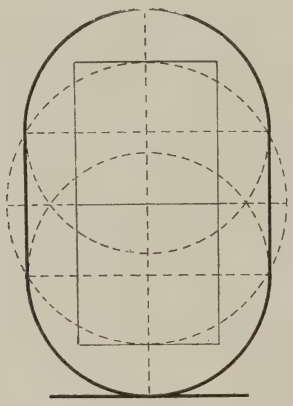


Fig. 2*a*.

shown in Fig. 1, the areas of the two squares being to each other as 1 to 3. PR is the diameter of a sphere circumscribing the cube whose edge equals KC, the radius of the sphere whose great circle is shown.

A cube circumscribed by a sphere is the basis of Ancient Universal Symbolism, the cube the determinate, symbolizing Matter, and the sphere the indeterminate, symbolizing Spirit.

Matter circumscribed by Spirit is a universal condition, and the symbol being general, according to the ancient theory is applicable to everything from an atom to a Universe, including Man.

The principal of duality as exemplified in opposites, as, for instance, good and bad, above and below, spiritual and material or animal, pervades all nature, and therefore the symbolism should include this feature.

What has been said about 30° north is true, also, of 30° south. "As above so below." Fig. 2*a* shows the double cube, the upper and lower quatenary, circumscribed by a capsule-shaped figure which constitutes the so-called Egg of Symbolism.

Examples of this figure are to be found on ancient temples and monuments in Egypt; the Ovals, containing certain ideographs, but without the double squares, constitute the cartouches of former rulers or other noted people of that country. One end of the oval is marked by a tangent line to designate the lower quatenary; logic-

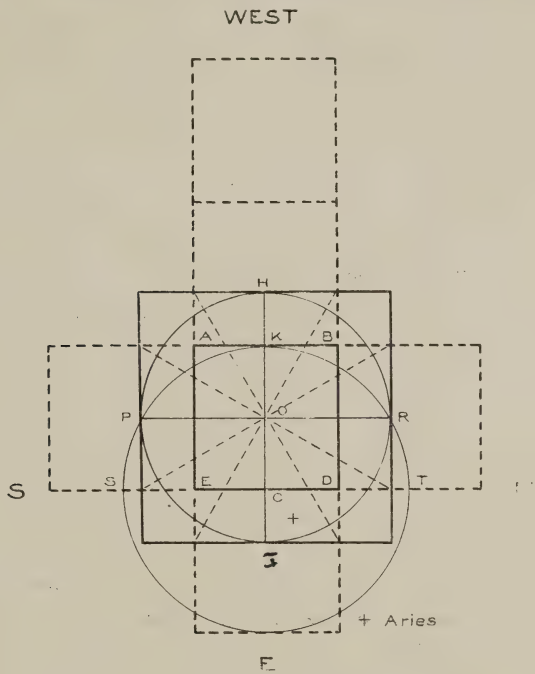



Fig. 2*b*.

ally, the lower end of the vertical type and the left-hand end of the horizontal type should be so marked. The Obelisk in Central Park, New York, contains examples of both forms marked in this manner.

Fig. 2 is general, and if in it CK represent the radius of the Earth, regarded as a sphere, the significance of *a pyramid on the 30th parallel north latitude* becomes apparent. HI becomes the line of the poles, and the pyramid base would circumscribe the circle of 30° north latitude. The division of the circle by 12 is

probably the basis of the division of the time of one revolution of the earth on its axis into 24 parts.

If ST be regarded as marking the plane of the ecliptic and KC represent the radius of the sun, the Celestial Zodiac results; this is usually defined as a zone extending about 8° or 9° each side of the ecliptic, probably to include the sun's equator, whose plane makes an angle of 7° 12′ with that of the ecliptic.

If the cube of Fig. 2 be unfolded in any of four directions, there will result a cross with a square zodiac displayed on it, as shown in Fig. 2*b*.

The signs of the zodiac are the 12 signs of a man, and according to the ancient theory, a man became a part of the universe through symbolic initiations which consisted of getting his signs into the zodiac. In Fig. 2*b* the cube unfolded symbolizes a man extended on the ground, and if a man or the figure of a man be placed upon the cross and bent into the form of a circle by bringing his heels and head together, his signs will come right with the zodiac. This symbolic initiation was termed "Breaking the Man on the Wheel."

The signs are usually represented as going from Pisces to Aries in the direction of the hands of a watch.

This is correct so far as the Earth zodiac is concerned.

The sun rises in the east, and as the evolution of man is upward through Matter to Spirit, from the Material to the Spiritual, the sun's course or apparent motion through the signs caused by the axial revolution of the earth should be symbolically upward from the feet to the head of the man.

Applying the same reasoning in the case of the Celestial Zodiac, it would appear that the signs should be reversed and that they should run from Pisces to Aries in the opposite direction to the motion of the hands of a watch. It may be remarked that this is the case in the Chinese Zodiacs.

As to the reason for the pyramid figure other than to determine a zodiac:

Mr. John Taylor of London, England, who died in 1864, was the first to advance the theory that when the Great Pyramid was built, it was proportioned as nearly as possible so that the height was the radius of a circle whose circumference equalled the periphery of the base or four times a base side; in other words, it was intended to represent or symbolize such a figure. Calling the height $h$ and

a base side $b$, the above relation would be expressed as follows:

$$h = \frac{2b}{\pi} \text{ whence } 2\pi h = 4b.$$

Such a pyramid is indeterminate, but comes within the scope of consideration symbolically. Conceive of two pyramids having a common square base, the one erect and the other inverted, their sides being at right angles where they intersect. Then the angle at the base of one will be the complement of the angle at the base of the other. Now, starting with their heights the same, as that of the erect pyramid increases that of the inverted pyramid decreases, and vice versa. When the height of erect pyramid satisfies the condition $h = \frac{2b}{\pi}$ the height of the invert, $h_1 = \frac{\pi b}{8}$, and the volume of the inverted pyramid becomes equal to $\frac{\pi b^3}{24}$, or ¼ of the volume of the sphere of which $b$ is the diameter.

The invert of the Great Pyramid could not, of course, be constructed, but it is a geometrical necessity and symbolism presents many suggestions concerning it.

The Perfect Pyramid, and by that is meant one in which the relation $h = \frac{2b}{\pi}$ obtains, is the connecting link between the cube and its circumscribing sphere; the relation being as follows: A cube is a mean proportional between one-third the volume of the sphere circumscribing it and a Perfect Pyramid whose base side equals the diameter of the circumscribing sphere, or whose base is three times the face of the cube. The foregoing is, of course, indeterminate and constitutes the basis of the claims that the Great Pyramid "squares the circle," etc.

Ancient examples of the Zodiac are to be found in the circular and square or quadrangular forms. In the temple erected to the Egyptian Venus at Denderah, Egypt, there were formerly specimens of each type, but the circular one was removed in 1820 and is now in Paris, being the property of the French Government. The square one still remains where originally constructed.

In the Congressional Library at Washington there is built in the floor near the main entrance a highly ornate square zodiac; its sides run north, south, east and west, and the east and west line through the center of the square separates the signs of Pisces and Aries on

the east side. Its signs are arranged in the usual way, following the motion of the hands of a watch.

MEASURES.

As the measures or standards of the Great Pyramid appear to be connected with the Zodiac, a brief discussion of them will be presented. There have been in times past many controversies concerning the length of the base side of the Pyramid, or rather the base sides, as owing to the irregularities of the site they are of different lengths, and in the discussions a mean of the lengths of the sides is generally considered. It has never seemed to the writer that this was a matter of much consequence, particularly in determining the standards of length, in accordance with which the Pyramid was built. The care shown in the construction of certain chambers in the interior, as described by pyramid authorities, notably Prof. Piazzi Smyth, appeared to offer possibilities in the way of accuracy that were lacking in any and all of the exterior features, after the casing had been removed. The chambers to be considered are known as the Queen's Chamber and the King's Chamber. These chambers lie east and west. The first mentioned is rectangular in ground plan with vertical side and end walls. The floor is rough, indicating that no accurate measures involving it were contemplated. The ceiling is made up of two sloping planes like the roof of an ordinary house. Fig. 3 is a section of the ceiling by a vertical north and south plane, the north being to the right, as most sections of the pyramid are made that way to show the Descending Passage. Leaving out of consideration the Niche, which has been chipped and disfigured to such an extent that accurate measurements of it are impossible at the present time, the two important features of this chamber are, first, that the two equal sloping parts of the ceiling make an angle of 30° with the horizon, and, second, that the width of the room is to its length as 10 to 11, suggesting the number 10, which appears more prominently in the King's Chamber. In Fig. 3 the angles ADB and ABD are each equal to 30°. Construct a circle passing through the three points B, A, D; then BA=BC and BD=BA$\sqrt{3}$. The line BA as measured equals 119.+ British inches, and the unit, accepting the suggestion afforded by the relation between the breadth and length, would be 11.9+ British inches. For convenience I called this a pyramid foot. This would indicate that the cubit, at least the pyramid cubit, is a derived measure, and that its length is equal

to a pyramid foot, or 11.9+ British inches multiplied by the square root of 3.

KING'S CHAMBER.

The floor plan of the King's Chamber is a rectangle of which the length is twice the breadth, and the latter, by all the authorities, is given as being slightly greater than the width of the Queen's Chamber. The latter is finished with white limestone, beautifully smooth originally, but now covered in most places with an incrustation of saline matter so hard and so closely adherent that, according to Professor Smyth, it can not be removed without destroying the original surface of the limestone. It is submitted that accurate end measures under such conditions are practically impossible and

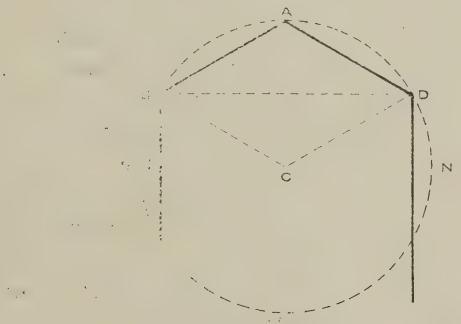



Fig. 3.

that the width of the two chambers was designed and intended to be the same, to-wit, 10 cubits. The King's Chamber is finished in polished granite with extremely fine joints, and it is submitted that here rather than in the Queen's Chamber extreme accuracy should be expected. Besides, the construction of the Queen's Chamber was apparently designed to suggest first of all the origin of the cubit, by its roof-like ceiling, and the angle which it makes with the horizon.

Adopting the suggestion of 10 contained in the Queen's Chamber, and the reason for this will be more fully developed later, the floor plan of the King's Chamber may be taken as 20 cubits long by 10 cubits wide.

The coffer in the King's Chamber is not necessarily a part of this discussion at this time, and besides it has been so battered and defaced by relic hunters that its original dimensions have been de-

stroyed. The world owes a debt of gratitude to Professor Smyth and others for their painstaking efforts in measuring and recording the dimensions of the chambers and their various features.

It may be stated that a vast number of people have visited the interior of the Great Pyramid since it has been possible to do so, and that most of the early visitors were actuated by avarice; in their explorations for suspected treasures they mutilated and almost destroyed the real treasures the pyramid builders had monumented in this vast structure with such care and foresight. The visitor of more modern times, the relic hunter, is rapidly completing the work of the treasure seekers, and but for the labors of Professor Smyth and other pyramidologists the real facts concerning the interior of the structure would at no very distant date be lost.

In Fig. 4 let ABDE be the face of a cube; circumscribe it by a sphere and construct the square zodiac as in Fig. 2. Complete the rectangle LMNO, OL being twice ON. If, now, AB be taken as 10 pyramid feet, ON becomes equal to 10 cubits. The area of the floor then is 20 $\sqrt{3}$ by 10 $\sqrt{3}$=600 square feet (pyramid), which is the same as the area of the 6 faces of the cube or of the cross formed by unfolding the cube as shown. This operation also completes the zodiac by intersections with the square IKNO. The perimeter of the floor of the King's Chamber is 60 cubits. From the above we have the numbers six hundred three score and six, "the number of a man," or 10.

The height of the King's Chamber above the original polished floor was one-half the floor diagonal. This makes the diagonal of the end of the room equal to 15 cubits, and the cubic diagonal of the room equal to 25 cubits, so that the construction of the King's Chamber involved the use of the numbers 10, 15, 20 and 25.

If the demonstration had started with the plain rectangle, and the same process been followed as in Fig. 1, using one-half the rectangle, or the square IKNO, it would have developed the "concealed measure" in the floor of the King's Chamber, or 10 pyramid feet, the length of the "rafter" of the Queen's Chamber.

The relation between the foot and cubit is the same as that between the sides of the inner and outer squares of the square zodiac, or the radius of the earth and the diameter of the 30th parallel.

If the signs be written in the zodiac at the eastern end of the King's Chamber, following the plan as given in the Congressional

Library at Washington, Aries would be as shown by the small cross, and the entrance to the chamber from the north, at the north-east corner, would be in the sign of Taurus, the neck of the man. The one woman, who is always present in a room of this character, is symbolized by the sign of Virgo. With this system of marking, the zodiac would correspond to the equatorial zodiac already referred to, but in the case of the Celestial Zodiac, according to my conclusions, the space marked by a cross would correspond to

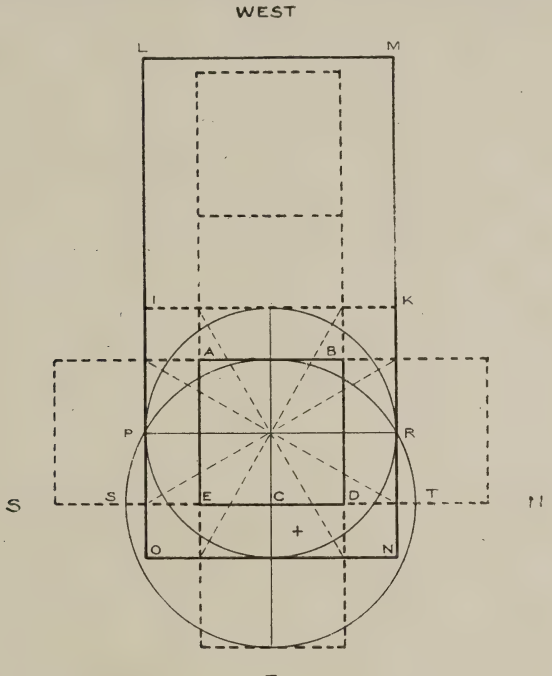



Fig. 4

Pisces with Aries to its left and the entrance to the chamber would be in the sign of Aquarius.

## UNIT OF VOLUME.

The method of obtaining the Unit of Volume for the Great Pyramid is that furnished in the discussion of the Molten Sea of King Solomon's Temple. While there appears as yet no positive authority for stating that the cubit of the Pyramid and that of the Molten Sea were of equal value, this in reality makes little or no difference, as the form of the expression deduced is general.

Two descriptions of the Molten Sea are given in the Bible, to-wit

in the 7th Chapter, I Kings, as follows: "And he made a molten sea, ten cubits from the one brim to the other; it was round all about, and his height was five cubits; and a line of thirty cubits did compass it round about." The other description is given in 4th Chapter, II Chronicles: "Also he made a molten sea of ten cubits from brim to brim, round in compass, and five cubits the height thereof: and a line of thirty cubits did compass it round about."

Based on the above, and the fact that the molten sea of Kings contained 2000 baths, while that of Chronicles contained 3000 baths, many theories have been advanced to account for the difference in volume, as the descriptions of the two appear at first glance to be practically alike. Sir Isaac Newton in a dissertation on the ancient cubit presented the following with reference to the vexed question: "Some compute the cubit from Solomon's brazen sea: lest any objection should be raised from thence, I shall briefly remark that the bottom of that sea ought not to be represented spherical as it generally is, but flat, in such a manner that all the water might run out for the use of the priests, and the vessel might stand commodiously upon the backs of the oxen, and the oxen not hinder the priests from coming to the cocks."

Some writers have held that the unit of measure, the bath, must have been different in the two cases.

The Bath was the ancient unit of liquid measure, and was equal in volume to the Ephah, the unit of dry measure. So far as my investigations have gone, the molten sea affords the only chance of determining the capacity of these units presented in the Bible, and the subject is one, therefore, from a scientific point of view, entitled to the most careful consideration and study. The two descriptions agree as follows:

*First.* Ten cubits from brim to brim, or from the one brim to the other.

*Second.* In being five cubits high.

*Third.* A line of thirty cubits did compass it around about.

The descriptions differ in this, that the sea in Kings was "round all about" while that in Chronicles was "round in compass." A sphere is round all about as well as round in compass, but a cylinder, while round in compass, is not round all about.

The Molten Sea furnishes a beautiful and striking example of symbolic or indeterminate geometry. Ordinarily, in the case of a circle or sphere, the radius or diameter is the known or assumed

part, but in this case it is the area of a circle that forms the basis for development.

The expression "ten cubits from the one brim to the other" establishes a square of which the side is ten cubits.

The radius of a circle whose area is ten cubits squared is as follows:

$$\pi R^2 = (10\sqrt{3})^2, \; R = \frac{10\sqrt{3}}{\sqrt{\pi}};$$

if now two prisms be conceived of, the one having a square base, to-wit $(10\sqrt{3})^2$, and the other a circular base of equal area, the common height being equal to the radius of the circular base, there will result a rectangular and cylindrical prism of equal volume, to-wit,

$$(10\sqrt{3})^2, \; 10\frac{\sqrt{3}}{\sqrt{\pi}} \text{ or } 3000\frac{\sqrt{3}}{\sqrt{\pi}},$$

the same "sea" in two forms. In the case of a sphere whose great circle equals ten cubits squared, its volume would be

$$\frac{4}{3}\pi(10\frac{\sqrt{3}}{\sqrt{\pi}})^3 \text{ or } 4000\frac{\sqrt{3}}{\sqrt{\pi}}; \text{ one-half of this would be } 2000\frac{\sqrt{3}}{\sqrt{\pi}};$$

the sea of Kings, a hemisphere, round all about. Whether the mouth of the Molten Sea was round or square, its area was ten cubits squared, or ten cubits from brim to brim. It would appear from the above that the bath and ephah were each equal in volume to a prism with a base one foot (pyramid) square, and a height equal to one foot (pyramid) multiplied by

$$\frac{\sqrt{3}}{\sqrt{\pi}}$$

a little less than a cubic foot. The expression for the height of the sea is

$$10\frac{\sqrt{3}}{\sqrt{\pi}}$$

which, according to the description given in the Bible, equals 5 cubits, making this form of the cubit equal to

$$2\frac{\sqrt{3}}{\sqrt{\pi}}.$$

I am inclined, however, to adhere to the mathematical notation, which would make the length of the cubit one foot multiplied by

$$\frac{\sqrt{3}}{\sqrt{\pi}}.$$

I am strengthened in this view by the fact that in a sphere the area of whose great circle is one square foot, the diameter of the circle of 30° is equal to

$$\frac{\sqrt{3}}{\sqrt{\pi}},$$

thus retaining the zodiac feature of the cubit relation. However, whether the cubit in question is

$$\frac{\sqrt{3}}{\sqrt{\pi}}$$

or twice that, would be developed in applying it in special cases.

The Molten Sea is represented in both Kings and Chronicles as resting on the backs of twelve oxen facing outwards, three to the north, three to the west, three to the south, and three to the east.

It is stated in II Kings, 16-17, "And King Ahaz * * * took down the sea from off the brasen oxen that were under it, and put it upon a pavement of stones."

When Nebuchadnezzar, King of Babylon, besieged and captured Jerusalem and carried its king into captivity (II Kings, 25), he sent back Nebuzar-adan, the Captain of the Guard, "and he burned the house of the Lord and the King's house and all the houses of Jerusalem, and every great man's house burnt he with fire."

12. "And the pillars of brass that were in the house of the Lord, and the bases and the brasen sea that was in the house of the Lord, did Chaldees break in pieces and carried the brass of them to Babylon."

16. "The two pillars, one sea and the bases which Solomon had made for the house of the Lord; the brass of all these vessels was without weight."

Again, in Jeremiah, 22nd Chapter, 20th verse, "The two pillars, one sea, and twelve brasen bulls that were under the bases, which King Solomon had made in the house of the Lord; the brass of all these vessels was without weight."

From the foregoing it would appear that the molten sea never had any material existence; it was purely a geometrical indeterminate, as the expression for its volume indicates.

What was the object sought? Answering to the results secured, it would appear that the object was to obtain a unit of measure of volume which should be a unit of measure of a rectangular and cylindrical prism as well as of a sphere or hemisphere; in other words, a universal unit of volume. For this reason the "Sea"

was described as "Molten," so that it could be cast into or made to assume the different forms already described.

The twelve "oxen" or "brasen bulls" merely symbolized the twelve radial lines of the zodiac, and it is to be noted that the order in which they are referred to is in the opposite direction to the motion of the hands of a watch.

The area of the spherical surface of the sea is 600 square feet, the area of the floor of the King's Chamber.

Although the molten sea never had a material existence, symbolically it still occupies the eastern end of the King's Chamber, and still rests on the twelve signs of the Zodiac on the "pavement of stones."

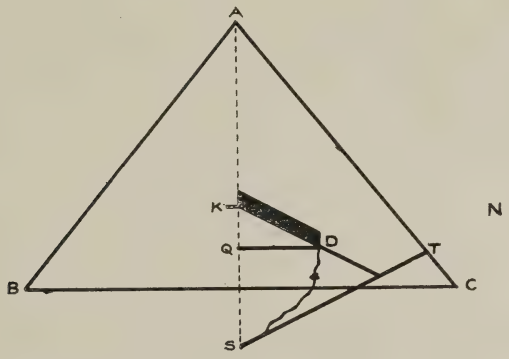



Fig. 5.
K. King's Chamber.
Q. Queen's Chamber.
T. S. Descending Passage.

The pyramid units of length are three in number, to-wit, the Foot, the Cubit and the so-called Sacred Cubit.

The first named are monumented in the length and breadth of the King's Chamber, and their values can be obtained by measurements of these dimensions. This room has been measured by many, but in most cases apparently more with a view of determining its form and proportions than of determining a standard of length; for example, Sir Howard Vyse in 1837 only measured to the nearest inch, which would of course, affect the value of the cubit in the second place of decimals.

So far as I can determine, the measurements of this chamber made by Prof. Piazzi Smyth in 1865 are entitled to great weight, as they were made with much care, using instruments of precision that had been compared with recognized standards.

The cubit as determined from a mean of the measurements of Professor Greaves, of Oxford, in 1637, of Mr. Lane in 1838 and of Professor Smyth in 1864 is 20.627+ British inches, from which the length of the pyramid foot is found to be 11.909+ British inches.

The so-called Sacred Cubit upon which the unit of volume was based, and as determined from the Molten Sea, was either 11.638 British inches or 23.276, depending on whether the mathematical notation is adopted,

$$10\frac{\sqrt{3}}{\sqrt{\pi}},$$

or the height of the "Sea" taken at 5 cubits. I am inclined to believe that the smaller value is the correct one. Every person who has entered and left the King's Chamber since it was completed has bowed his or her head over the "Sacred Cubit," as the length of the Ante-chamber is the diameter of a circle whose area is 5 cubits squared to-wit,

$$2\left(5\frac{\sqrt{3}}{\sqrt{\pi}}\right).$$

The unit of volume contained 1650.488+ cubic inches (British) corresponding to the Bath and Ephah of the Bible.

There appears to have been no connection between the foot and cubit measures and any dimensions of the earth, other than through the relation of 1 to the $\sqrt{3}$, which also applies to the Zodiac; the actual values of the foot and cubit being the "measures of a man," that is devised or fixed by man, just as the number 10 was called the "number of a man."

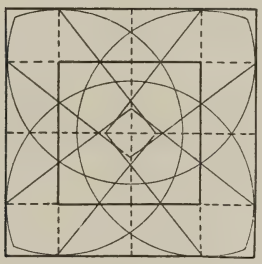
In conclusion I would state that there appears to have existed in ancient times about the same confusion as to standards of length as now, with this difference: in ancient times the unit of length, whatever its value, seems in most cases to have been called a cubit, at least is so termed in modern times, while at the present time each nation generally has a distinctive name for its standard of length.

It would appear logical to designate the unit of length of the Pyramid as a *cubic* instead of a cubit, since it is the cubic diagonal of a cube whose faces are one foot square.

The last plate shows symbolically the base of a Perfect Pyramid, i. e., one in which the height equals twice the base side divided by $\pi$. There appears, first, the square Zodiac; second, the Lotus with the jewel at its heart; third, the "All Seeing Eye," symbolized by the

horizontal and vertical ovals, the jewel forming the common iris; fourth, "The Flaming Sword," turned every way, etc., symbolized by the four short swords with their points at the corners of the square, the jewel forming the common hilt at the center. The term "flaming" is doubtless due to the jeweled hilt.

NOTE. In Plates 2*b* and 4 the points of the compass are changed so that north is to the right side of the plate. This was done for the reason that the sections of the Pyramid are usually made so as to show the angle of the Descending Passage, which comes in on the north side, to the right.



# A BRIEF HISTORY OF THE PANAMA CANAL

BY

LIEUTENANT CHAS. K. ROCKWELL,
*Corps of Engineers*

Professor Johnson* has well named his admirable history, "Four Centuries of the Panama Canal," for that stupendous Isthmian project, though but now well under way, was, nevertheless, conceived by brilliant minds several centuries ago.

In 1245, Pope Innocent the Fourth sent one Friar John, as a missionary to the Great Khan. Later, in 1253, King Louis of France sent William of Rubriquis for a similar purpose. Both of these men upon their return reported the presence of a great sea to the east of Cathay. With such a sea to the east of this empire and another on the west of Europe, what could be more natural than a dream of a new glorious higway to Cathay?

In fact, it was such a highway—and no new continent—that Columbus sought when he embarked in 1492. He landed in the Bahamas and firmly believed that he was among the islands of the Indian Ocean, showing such belief by his letters and by his naming the inhabitants of San Salvador, Indians. He was strengthened in his error by his second, third, and fourth voyages. On these voyages he believed himself to be among the numerous islands off Cipango described by Marco Polo, and that Cuba was Cathay; consequently, he sought to return to Europe by way of the Indian Ocean. He never reached the Isthmus, however, and that honor fell to the lot of Rodrigo de Bastidas, of Spain, in the year 1500.

In 1505, La Cosa and Amerigo Vespucci explored the Gulf of Darien. In 1506, Juan Diaz de Solis and Vincente Ganez Pinzon touched at Jamaica, and from there voyaged to Yucatan. In 1508, Alfonso de Ojeda, Spanish governor of the Caribbean coast of Colombia, penetrated far inland and died while in search of the passage. Next, Balboa, governor of Castilla del Oro, driven to the

*Professor Willis Fletcher Johnson, whose valuable book on the Panama Canal has been the chief source of the information contained in this article, has kindly approved the publication of this paper.

pursuit of such a goal by the necessity of holding his position through some grand discovery, crossed the Isthmus, and on September 25, 1513, discovered the Pacific Ocean.

In no way daunted by these failures, many others from Europe sought the strait, and among these was Giovanni da Verrozzano and Jacques Cartier, to whom France owed her Canadian colony; Magellan, who sailed around the great cape; and Hernando Cortez, whose explorations in Mexico made him famous.

The failure of such men to find "the hidden strait" created a doubt as to its existence, and in 1529 the idea of an artificial passage was conceived by Alvaro de Saavedra Ceron. He had been a companion of Balboa and was, for the times, well conversant with the Isthmus. It was he who drew up crude plans for a canal at Panama and discussed the four great probable routes, Darien, Panama, Nicaragua, and Tehuantepec. This man, who died while in the midst of his work, by such advanced thoughts and by such appreciation of the advantages of a canal route over the long passage around the Horn, certainly stands out in bold relief from his age. Though dead, the pregnancy of his idea remained, and both Charles the Fifth and Philip the Second dreamed of such a project until turned to other channels by the pressure of state affairs. About this time, too, the British Freebooters became active on the Spanish Main and the canal project was laid aside and practically forgotten until the nineteenth century.

In the nineteenth century, however, lawlessness along the Isthmus had subsided. Internal dissensions no longer entirely engaged the attention of the nations, and so the canal was once more agitated. Attention was invited to it by the writings of such men as Humboldt and Goethe, and certain interested States on the Isthmus also urged it. As a result, about 1825, concessions were granted by both Panama and Nicaragua, and companies were formed. Through various causes these companies failed; Americans had been interested in them, however, and such fact kept the idea alive in this country. Consequently, other projects relating to the subject were constantly proposed and gradually the Government became interested and began to seriously consider the subject. Thus it was that the British aggressions upon the Isthmus at such a time naturally stirred the United States.

The British since the seventeenth century had gradually been unlawfully increasing their domain in Central America, but the United States having no apparent interests there and being busy

in other affairs had paid no attention. Its resentment now was aroused, not by the unlawful expansion of British control, but by the fact that such expansion threatened its trade routes to the Pacific coast. As a result in order to guard these routes, a treaty was made in 1846 with the Republic of New Granada which was to have a most decisive effect on all interoceanic projects. By this treaty "the United States secured the exclusive rights of transit across the Isthmus of Panama, including all routes in the country between the Chiriqui Lagoon and the Atrato River, and in return undertook the maintain the neutrality of such routes and of any line of traffic which might be established on that Isthmus, and also the sovereignty of the Isthmian territory against any attack by alien powers."

In Nicaragua the effect of British extension was immediately felt, and American commercial interests were greatly hampered. The interests of the United States and Great Britain so conflicted there that an acute crisis developed, which after much diplomatic intercourse, in which the United States made a poor showing, was tided over by the famous Clayton-Bulwer treaty. This treaty "provided that neither the United States nor Great Britain should exclusively control the Nicaragua canal or build any fortifications along it; that neither should ever take possession of, fortify, colonise, or exercise dominion or protection over any part of Central America; that they should mutually guard the safety and neutrality of the proposed canal, and should invite all other nations to do the same; that both should give aid and support to any satisfactory company which would construct the canal; and that thus a general principle should be established for application to all Isthmian canals or railroads at Panama or Tehuantepec as well as at Nicaragua."

This treaty, though regarded as extremely satisfactory by the American nation at the time it was signed, was in reality a most stupid political blunder. It was not applicable to the British claims in the Bay Islands and on the Mosquito coast, thus confirming Britain in all her disputed claims and violating the Monroe Doctrine; it was in direct opposition to the treaty of 1846 made with the Republic of New Granada; and it hampered greatly the policy put forth later of "an American canal under American control."

The disputes, which soon arose because of this treaty, did not, however, at the time interfere with canal projects, and many preliminary surveys were made both by the French and the Americans.

France, however, was the most active, and in 1879 held an International Engineering Congress, presided over by De Lesseps, the famous builder of the Suez Canal. This congress considered the different routes and reported in favor of that which traversed Panama. This route was the one advocated by De Lesseps, though opposed by the other engineers of the convention, of whom there were few, the congress being more speculative than engineering in character. Accordingly a company was formed, a concession secured, and the construction entrusted to De Lesseps. The project called for a 28-foot tide-level canal, to cost $132,000,000 and to be under European control.

Such a plan aroused strong criticism in the United States, as it was a threatened infringement upon both the Monroe Doctrine and the Clayton-Bulwer treaty. De Lesseps naturally tried to smooth matters over, but was unsuccessful, and President Hayes further intensified matters by sending a most emphatic message to the Senate, in which he stated that it was the natural "right and duty of the United States to assert and maintain supervision over any intervening canal across the Isthmus."

Public opinion of such character, and that strong barrier, the treaty of 1846, effectually killed the idea of European control of the canal. De Lesseps, in turn, in an attempt to protect his own canal, tried, by a lavish expenditure of money and other means, to kill the United States-Nicaraguan canal, which was being promoted at that time, and also to have the treaty of 1846 abrogated. He failed in his purpose, however, though the idea of such a United States canal later came to naught, due to the blundering diplomacy of Secretary Blaine in his attempt to have the Clayton-Bulwer treaty abrogated. Thus it was that in 1881, when the French company actually began work, both the Clayton-Bulwer and the treaty of 1846 were still in effect.

In this year the company made a very showy opening, and for the seven years following the world, unknowingly, was a witness to a piece of gigantic graft and thievery. Such a system naturally resulted in bankruptcy, and the amount spent, $400,000,000, compared to the work done, was appalling. Nevertheless, the French, though astounded by such knavery, attempted to reorganize and again struggle towards the goal. A receiver was appointed, affairs put in businesslike shape, and a new company finally formed in 1893.

In the meantime, Nicaragua had loomed forth as a dangerous

rival. While the French company was in the throes of reorganization, concessions had been granted by that Government to an American company, and, in 1890, work had actually been started by this company at Greytown. Though it did little work, it nevertheless had an important influence upon the present interoceanic project, for when the company fell into difficulties, strong influence was brought to bear upon Congress to help it out. Congress became interested, and from that time on an enthusiastic minority constantly championed the canal. In 1895, a Commission was appointed to report upon the scheme. This Commission decided that the plans of the company were practicable. Such a report renewed the enthusiasm, and in 1897 another Commission with greater power and funds was assembled. However, due to the fact that the Spanish-American War broke out in 1898, this report, though favorable, for the time seemed likely to come to naught.

The Spanish-American War was short, however, and, unexpectedly, an event in it aroused widespread enthusiasm for a quick passage between the oceans. This event was the record-breaking run of the "Oregon" from San Francisco to Cuba. Such a trip awoke all to the value of a canal, and the people began to clamor for it, and also for the abrogation of the Clayton-Bulwer treaty. As a result, a third Commission was appointed to investigate the Panama and Nicaragua routes, and negotiations, relative to the treaty, were commenced by Secretary Hay.

The results of both these operations were successful. A new treaty, called the Hay-Pauncefote treaty, was signed in 1901, which gave the United States complete power "to construct, operate, and control without cooperation" an Isthmian canal. A little later the Commission reported. It had examined the two routes and readily decided that the Panama one was the better. The reasons for such superiority, as stated by General Abbot, are as follows:

The Panama route at that time had two good harbors already existing. A good railroad was in position along the entire route. Construction of the canal was well under way and the remaining obstacles were definitely known. No new work was necessary which was not justified by former engineering experience. Except the works at Bohio, no difficult construction work was to be accomplished where the annual rainfall exceeded 93 inches. The route lay entirely within the bounds of Colombia. The distance to be lighted and supervised was but 46 miles. There were no active volcanoes within a radius of 200 miles and earthquakes were,

therefore, less to be expected. The cost already estimated on the prepared plans was but $100,000,000. The ports were known to be of easy approach. The length of the route was but 46 miles and the time of transit fourteen hours. The summit elevation was, at the most, 103 feet, and maybe considerably less. The locks were to be double from the opening of the canal, the chambers 738 by 59 and 738 by 82 feet, respectively, with intermediate gates. The curvature was gentle and the smallest radius 8,200 feet. Of the 46 miles of length, 26¾ were straight and 15 had radii exceeding 9,800 feet. There were no troublesome winds or river currents, even in time of flood.

The Nicaragua route, on the other hand, had to have two harbors created, one of which, at Greytown, presented great natural difficulties. There was no railroad, and its construction would be laborious. No construction had yet been undertaken and many details of the project were not yet settled upon. Several dams would have to be built of a character never before attempted. The embankments necessary along the canal would always be a source of danger. All the difficult work would have to be done in a region of 256-inch annual rainfall. The route lay along the border of Nicaragua and Costa Rica, thus furnishing a cause of conflicting interests. The distance to be lighted and supervised was about 176 miles. There were active volcanoes near the route, and in 1898 an earthquake had created considerable havoc. The cost, estimated on doubtful data, was over $133,000,000. The access to ports was not secure, especially on the Atlantic Coast. The length of route was 176 miles and time of transit forty-four hours. The summit elevation was 110 feet. The locks were to be single and only 650 by 80 feet. The curvature was too sharp, the smallest radius being 4,000 feet. There were heavy winds and strong river currents to be encountered.

Nevertheless, in spite of such obvious advantages of the Panama route, the Commission stated that, though the Panama was cheaper, the concession was unobtainable from the French company, and it, therefore, recommended the Nicaragua canal.

A report of this character was an extremely shrewd move, for it quickly brought the French company to terms. The company, seeing the impossibility of competing against the United States Government, at once opened negotiations with Colombia for permission to sell—was successful—and agreed to dispose of its rights for the proffered $40,000,000. The Commission accordingly re-

versed its recommendation, and in 1902 a bill was passed by Congress authorizing the building of the Panama Canal.

At this point the Colombian Government stepped in and attempted to hold up the United States. It craftily saw that a two years' delay meant the lapsing of the French charter, with the loss of the $40,000,000 to that company, and its own consequent gain of that amount. Accordingly it desired to delay negotiations, and the attempt was almost the ruination of the Panama project. The people of Panama, however, made desperate by the thought of such a loss to their country, in 1903 revolted, obtained their independence, and set up a republican form of government.

Much comment has been made and many sarcastic political articles have been written upon the part the United States played in this revolution. From the known facts, not enough credit has been given to the work of the patriotic few who desired the welfare of their country, and too much suspicion cast upon the United States. However, be that as it may, one thing is certain: the revolution was a success, and that same year the Hay-Bunau-Varilla treaty was negotiated.

This treaty gave the United States all rights upon the Isthmus of Panama necessary for the construction, control, and operation of an interoceanic canal. Thus it was that in the year 1903 the choice of a route was at last settled, the Monroe Doctrine firmly established as a national policy in all American minds, and an "American canal under American control" assured.

By an act approved in 1902 the President had been charged, through a Board, with the construction of a canal, providing terminal harbors, and the necessary provisions for protection. Accordingly on February 9, 1904, the President appointed a Commission. Its duties were wide and various, including the making of the necessary surveys and preparing the needful plans and specifications; the supervision of the engineering, hydraulic, and sanitary works; the enaction of proper legislation for the Zone; and the administration of military, civil, and judicial affairs.

Accordingly, the committee went to work organizing the necessary departments and assuming control of the Zone and the French company's property. Mr. Wallace was selected as chief engineer in 1904, and repaired to the Isthmus immediately to take charge of the engineering work. His position there afforded him an opportunity to examine local conditions, and he early showed strong prejudice in favor of De Lessep's old sea-level project, which, after

the tremendous failure in 1889, had been condemned by all subsequent French and American commissions. Upon the strength of his recommendations the engineering committee of the Commission, in 1905, recommended such a type, but this recommendation was pidgeon-holed by the Board and no action taken upon it.

In this same year the Commission was reorganized by an order in which the President stated that "the practical results of the operations of the Isthmian Canal Commission, appointed and acting under previous executive orders, has not been satisfactory, and requires a change in the personnel of the committee and in the instructions for its guidance." The new Board had definite duties and definite orders as to their scope.

It was during this reorganization that Chief Engineer Wallace resigned, and, after a stormy interview with Secretary Taft, was also requested to retire from the Board, and, later, was severely arraigned by the latter for his defection as chief engineer. Mr. J. F. Stevens was immediately appointed to fill the vacancy of the chief engineer, and shortly after this a Board of Consulting Engineers was appointed "for the purpose of considering the various plans to and by the Isthmian Canal Commission for the construction of a canal across the Isthmus of Panama between Christobal and La Boca."

The Board convened by this order accordingly met and considered the subject for several months. The members finally reached their conclusions, but were hopelessly divided. The majority, made up principally of all the foreign members, advocated a sea-level canal similar to that recommended in 1905, but with important modifications. The minority, all Americans, a lock canal with an 85-foot summit level. The two reports were submitted to the Commission and the majority endorsed the minority report of the Board of Engineers, as did Chief Engineer Stevens and, later, Secretary Taft and President Roosevelt.

The influencing features in each case can, perhaps, be best shown by the President's instructions to the Board of Engineers as to the essential features to be considered in determining the type of canal, and by extracts from the reports later submitted in favor of each type. President Roosevelt outlined the purpose as follows:

"There are two or three considerations which I trust you will steadily keep before your minds in coming to a conclusion as to the proper type of canal. I hope that ultimately it will prove possible to build a sea-level canal. Such a canal would undoubtedly be the best in the end, if feasible; and I feel that one of the

chief advantages of the Panama route is that ultimately a sea-level canal will be a possibility. But, while paying due heed to the ideal perfectibility of the scheme from an engineer's standpoint, remember the need of having a plan which shall provide for the immediate building of a canal on the safest terms and in the shortest possible time. If to build a sea-level canal will but slightly increase the risk, then, of course, it is preferable. But, if to adopt the plan of a sea-level canal means to incur a hazard, and to insure indefinite delay, then it is not preferable. If the advantages and disadvantages are closely balanced, I expect you to say so. I desire also to know whether, if you recommend a high-level multi-lock canal, it will be possible, after it is completed, to turn it into or substitute for it, in time, a sea-level canal, without interrupting the traffic upon it. Two of the prime consideration to be kept steadily in mind are:

"First: The utmost practicable speed of construction.

"Second: Practical certainty that the plans proposed will be feasible; that it can be carried out with the minimum risk.

"The quantity of work and amount of work should be minimized so far as possible.

"There may be good reason why the delay incident to the adoption of a plan for an ideal canal should be incurred; but if there is not, then I hope to see the canal constructed on a system which will bring to the nearest possible date in the future the time when it is practicable to take the first ship across the Isthmus; that is, which will in the shortest time possible secure a Panama waterway between the oceans of such a character as to guarantee permanent and ample communication for the greatest ships of our navy and for the larger steamers on either the Atlantic or the Pacific. The delay in transit of the vessels, owing to additional locks, would be of small consequence when compared with shortening the time for the construction of the canal or diminishing the risks in its construction.

"In short, I desire your best judgment on all the various questions to be considered in choosing among the various plans for a comparatively high-level multi-lock canal, for a lower level with fewer locks, and for a sea-level canal. Finally, I urge upon you the necessity of as great expedition in coming to a decision as is compatible with thoroughness in considering the conditions."

The majority of the Board concluded as follows: "It is the belief of the Board that the essential and indispensable features of a convenient and safe ship canal at the American Isthmus are now known; that such a canal can be constructed in twelve or thirteen years' time; that the cost will be less than $250,000,000; that it will endure for all time.

"The Board does not believe that a provisional treatment of this great question would yield results which would be satisfactory to the American nation or advantageous to American commerce, or that such treatment would be in consonance with the increase of

population, of trade, and of wealth which will surely take place during the next half century in the Western Hemisphere."

The report of the minority of the Board differed decisively as to cost and time, and stated: "In view of the unquestioned fact that the lock canal herein advocated will cost about $100,000,000 less than the proposed sea-level canal; believing that it can be built in much less time; that it will afford a better navigation; that it will be adequate for all its uses for a longer time, and can be enlarged, if need should arise, with greater facility and less cost, we recommend the lock canal at elevation 85 for adoption by the United States."

Mr. Stevens said: "The sum of my conclusions is that, all things considered, the lock or high-level canal is preferable to the sea-level type, so called, for the following reasons:

"It will provide as safe and a quicker passage for ships and, therefore, will be of greater capacity.

"It will provide, beyond question, the best solution of the vital problem of how safely to care for the flood waters of the Chagres and other streams.

"Provision is made for enlarging its capacity to almost any extent at very much less expense of time and money than can be provided for by any sea-level plan.

"Its cost of operation, maintenance, and fixed charges will be very much less than any sea-level canal.

"The time and cost of its construction will be not one-half that of a canal of the sea-level type.

"The element of time might become, in case of war, actual or threatened, one of such importance, that measured, not by years, by months, or even days, the entire cost of the canal would seem trivial in comparison.

"Finally, even at the same cost in time and money for each type, I would favor the adoption of the high-level lock-canal plan in preference to that of the proposed sea-level canal."

The majority of the Commission reported as follows: "It appears that the canal proposed by the minority of the Board of Consulting Engineers can be built in half the time and a little more than half the cost of the canal proposed by the majority of the Board, and that when completed it will be a better canal for the following reasons:

"It provides greater safety for ships and less danger of interruption to traffic by reason of its wider and deeper channels.

"It is in much less danger of damage to itself or of delays to ships from the flood waters of the Chagres and other streams.

"It provides quicker passage across the Isthmus for large ships or large traffic.

"Its cost of operation and maintenance, including fixed charges, will be less by some $2,000,000 per annum.

"It can be enlarged much more easily and cheaply than can a sea-level canal.

"Its military defence can be effected with as little or, perhaps, less difficulty than the sea-level canal.

"It is our opinion that the plan proposed by the minority of the Board of Consulting Engineers is a most satisfactory solution of the problem of an Isthmian canal, and, therefore, we recommend that the plan of the minority be adopted."

The minority report of the Commission stated: "The undersigned does not concur in the preference for a lock canal, as expressed by the Commission, but regards a sea-level canal, as proposed by the majority of the Board of Consulting Engineers, a better canal for commercial and military purposes.

"Because, while for exceptionally large vessels, such as built for Atlantic liners, the time of transit might be as long as, or longer than, in the lock canal, the average time of transit of the class of vessels which will use the canal for a long term of years will be less than in the lock canal.

"Because the risks of interruption to traffic from accident are deemed greater in a high-level canal with six locks than in a sea-level canal with a tidal lock, notwithstanding the greater distance in the latter canal which might be obstructed by a sunken vessel.

"Because the cost of maintenance and operation of the sea-level canal will be less.

"Because in the enlargements to accommodate increase in traffic the relative advantages of the sea-level canal will increase.

"Because it is a better, safer, and more capacious canal from a military standpoint."

Secretary Taft in his letter of recommendation to the President said: "In the high-level canal a vessel of the dimensions noted (i. e., the largest vessel afloat) would have, with the exception of the 4.7 miles where the width is only 200 feet, ample leeway for safe navigation and good speed, without objectionable currents and without difficulties at the points where changes in course are necessary.

"With the proposed sea-level canal conditions are different. The depth is but 2 feet greater than the draught of the ship, not sufficient to permit her to proceed under her own steam, except at great risk; 21 miles of the canal is not sufficiently wide for two such vessels to pass; currents caused by the regulation of the Chagres and by the flow of other streams into the canal, and its many curves, combine to increase the difficulties and dangers of navigation. In short, the sea-level canal recommended is 'not of sufficient capacity and depth' to afford convenient passage for vessels of the largest tonnage and greatest depth, and can be made so only by materially increasing the depth and width, and at a considerable increase of time and money. If the suggested width of 150 to 200 feet is the greatest width economically permissible for a sea-level canal, the cost of the enlargement required must be prohibitive.

"It, therefore, follows that the high-level canal more fully meets the requirements of Congress."

These, then, were briefly the principal arguments of the various reports submitted to Congress by the President, and it was based upon their different strengths and weaknesses that Congress finally decided in June, 1906, upon the lock canal at an 85-foot elevation.

Thus it was that the question of route and plan were settled, and but one thing remained undecided in the long and laborious stage of preparation. It was the question whether the work should be performed by contract or day labor. At first the idea of contract in terms of a percentage upon the estimated cost of construction was favorably considered and bids were actually called for and made upon such a plan. No award was immediately made upon these bids, however, and the matter was still under consideration when the President visited the Isthmus.

This visit was made in November, 1906, and the President personally inspected the entire route. The result of his observations was a complete change in the executive management. Seven departments were created, and it was definitely decided that the work should be done by day labor under the charge of the United States Corps of Engineers. Accordingly the resignation of Chief Engineer Stevens was accepted, and Maj. G. W. Goethals was put in charge of the construction. This step, taken in February, 1907, marked the close of the preliminary stage.

At the present time, the second stage—that of execution—of the great project is well under way. The management has been excellent, the work rapid, and the end seems not far distant.

Success will be far-reaching. Our seaports will be benefited, our naval strength increased, the world's commercial routes greatly shortened—all accomplished by the opening of this great artificial highway, of which De Ceron and other great men dreamed.

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## Balloon Guns.

Every step in advance in offensive warfare stimulates the inventive genius of man to devise a means of neutralizing the new danger. How often we read that some recent invention has revolutionized war and that soon it will be impossible to place an army in the field or to maintain it against the new powers of annihilation! And yet defensive warfare continues to develop parallel with the advances made in means of attack So a very natural consequence of the rapid strides achieved in the solution of the problem of aerial flight, which threatened to afford a line of attack beyond the

reach of existing field guns, is the production of special guns.

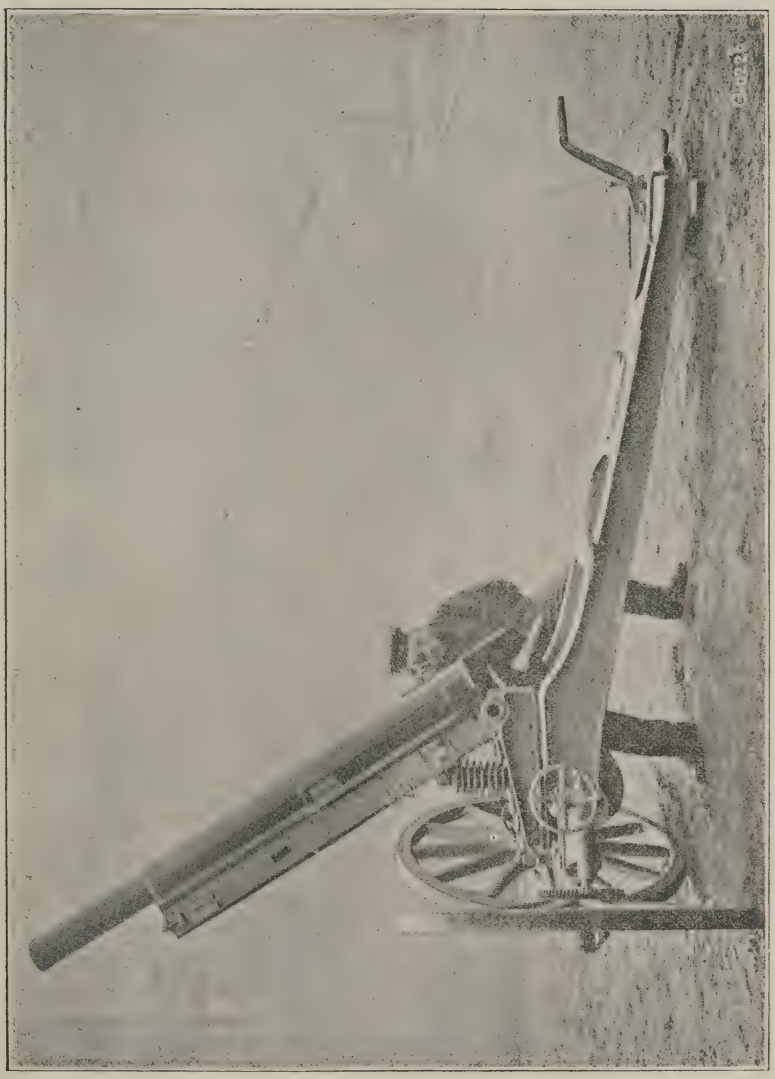
The accompanying cut of a Krupp gun, intended for special use against balloons and other air ships, is reproduced from the *Revue Militaire Suisse* for December, 1908. This piece is of 6.5 cm. caliber, and throws a 4-kilogram projectile at a muzzle velocity of 620 meters per second. Although a practicable field gun for ordinary service, this weapon possesses several unique features to meet the special conditions for which it is designed.

Since the enemy may appear from any direction, all-around fire is necessary and is secured by the ingenious device of utilizing the recoil spade at the end of the trail for a pivot. In order that the carriage may be traversed, the axles are so arranged that they may be swung into positions radiating from this central point. This brings the wheels into planes tangent to the circular path upon which they are to run.

The increased vertical range of fire is secured by pivoting the top carriage at the breech of the gun in such a manner that the recoil cylinder and return springs are elevated and lowered with the gun itself. As high an angle as 60° is attained in this way. At such an angle it is apparent that great difficulty would be met in placing a cartridge upward in the chamber and retaining it there while the breech mechanism is operated; but this difficulty is obviated by an automatic fermature which locks the cartridge in place and at the same time throws the hand of the operator out of the way of the closing breech-block.

The mechanical problems presented are more readily overcome than those connected with the accurate laying of this gun. The proper elevation for a shot at an air ship will depend upon the horizontal distance to the target and upon the altitude of the target as well, and both these are very difficult to measure. The distance direct to the target, however, may be determined by a telemeter, and the elevation of the angle of sight may also be measured. From these may be computed tables giving the proper elevation, and allowance may be made for drift, wind, and motion of the target. Should the site be inclined, a correction for "canting the piece" will be required. The necessary computations and corrections may be expedited by mechanical means. A prismatic eyepiece enables the gunner to stand in a convenient position while aiming at extreme elevations.

In order to observe the accuracy of the fire, smoke-producing



6.5 cm. Balloon Gun, Krupp System.

projectiles are used, with which satisfactory observation of fire has been attained abroad.

In addition to the field gun shown, a 7.5-cm. gun is made, which is mounted upon an automobile, and a 10.5-cm. gun for batteries of position gives greatly increased range. Such weapons should be able to throw an enormous number of shrapnel bullets, which, considered in connection with the extreme vulnerability of all air ships, should make attack or reconnaissance by means of such vehicles somewhat unattractive.

# Effect of Vertical Rigidity in a Horizontally Framed Lock Gate

*BY*

Captain P. S. Bond,
*Corps of Engineers*

The two most recent analyses of the stresses on lock gates which the writer has seen are "Mitering Lock Gates," by Lieut. (now Lieutenant-Colonel) H. F. Hodges, and the elaborate mathematical discussion of Mr. S. H. Woodward in the report of the Board of Engineers for Deep Waterways.

Both of these discussions are based on the assumption made by Lieutenant Hodges in paragraph 5 and Fig. 1, pages 8 and 9, of "Mitering Lock Gates." Unless the assumptions are correct, much of what follows is necessarily in error. It is the writer's opinion that there are errors in these fundamental assumptions.

That the stresses in the horizontal frames of a lock gate are modified by the presence of verticals there can be no question; but that relieving the lower frames from some pressure by introducing the support of a sill should, through the influence of the verticals, *increase* the stresses in the upper frames is not so apparent.

It is proper, in the first place, to consider the manner in which a horizontally-framed lock gate is constructed. The horizontal frames are continuous across the gate, being ordinarily uniformly spaced, but of unequal weight. The verticals consist usually of diaphragms introduced between successive horizontal frames, somewhat as indicated in the accompanying figure (Fig. 1). These diaphragms may or may not be placed one above the other.

In all horizontally-framed gates the vertical rigidity of the diaphragms or frames intermediate between the quoin and miter post is less than that of the horizontal frames. In those gates that the writer has seen it is considerably less. The reasons for this are obvious. The diaphragms are usually fewer in number; they are usually at least as long from sill to crest as the horizontals from post to post; they are of lighter section, and, lastly and chiefly,

*they are discontinuous*, being interrupted at each horizontal frame. Hence, in considering the effect of the verticals upon the distribution of the stresses in the horizontals it seems proper to consider the effect of a single diaphragm (A in Fig. 1) upon the frames adjacent thereto.

The diaphragm A may be considered as a cantilever loaded at one end and supported at the other. Now, if the deflections of the two frames B and C are equal—that is, if they are the same distance downstream and directly over each other—there will be no stress in the cantilever A. If, however, the deflection of the frame B is greater than that of the frame C, the cantilever is at once placed in stress, resisting the tendency of the frame B to increase its deflection relatively to that of the frame C. The effect of the diaphragm, therefore, is to transfer some of the stress in B to C and its tendency is to equalize the deflections of the two frames. And in every such case a portion of the stress on the frame which has the greater deflection is transferred to the frame which has the less deflection. This, of course, depends upon the diaphragm being securely fastened at *a* and *b;* in other words, upon its rigidity.

This reasoning applies upon any two frames connected by a diaphragm. Hence, the effect of such a system of verticals is to relieve the stress upon all frames which have a greater deflection than the adjacent frames and to increase the stress upon those frames which have a less deflection than the adjacent frames. In some cases a frame may bear part of the load of one adjacent frame and transmit part of its load to the other adjacent frame.

It now remains to apply this theory to show the effect of the support of the sill upon the stresses in the horizontal frames, in a manner analogous to that of Lieutenant Hodges in paragraph 5 of "Mitering Lock Gates."

Now let it be supposed that the frames are proportioned for equal deflection according to the depth, and that the support of the sill is removed. Then the frames will be equally deflected and will be, after bending, with their center points along AB. (Fig. 2.) Again, let it be supposed that *the same leaf* is supported at the sill. Then it is evident that the stress upon the lower frame (1) is relieved due to this support, and the frame will take the position 1′. Then the stiffness of the diaphragm between 1 and 2 is brought into play, relieving the stress upon frame 2, and *decreasing its deflection* until it takes a new position, 2′. The deflection of frame

2 in its new position will be less than the deflection of frame 3 in the first position, hence, the frame 2′ relieves the frame 3 and diminishes its deflection until it stands at 3′. In like manner, each frame relieves the frame next above it and diminishes its deflection from that of the first position. The new position of the leaf is 1′ 6′, and since the deflection of each frame is less, the stresses in each frame are less than before the support of the sill was introduced.

It may be that the upper frames would be made relatively stronger than the lower frames, in accordance with Lieutenant Hodges' rule. Then, if there were no support at the sill the leaf would be in the position *ab*, Fig. 3. In such a case the lower frames having a greater deflection would transfer a portion of this

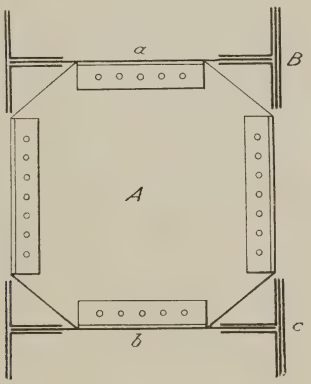



Fig. 1.

stress to the upper frames and be relieved a corresponding amount. The upper frames would then receive stresses greater than that due to the depth and the lower frames would receive stresses less than that due to the depth. The effect of the support of the sill, however, is to relieve the stress on every frame, since if the deflection of any frame is decreased, the deflection of the adjacent frame is decreased, no matter which has the greater deflection.

Hence, in a horizontally-framed gate the stresses due to the depth are modified by the presence of the verticals, the upper frames receiving loads greater than those due to the depth if they are constructed relatively stiffer than the lower frames. *The effect of the support of the sill, however, is in every case to diminish the deflections of, and the stresses in all, of the frames.* The upper frames may still receive stresses greater than those due to the

depth, but less than those they would have were the support of the sill removed.

The stresses on individual frames, therefore, depend upon the load due to the depth and upon the relative deflections of these frames as compared to the adjacent frames on either side.

The writer has had neither the time nor the opportunity to investigate the effect that this theory, if true, would have upon the design of horizontally-framed mitering lock gates. The problem is certainly a very intricate one, since a change in the deflection of

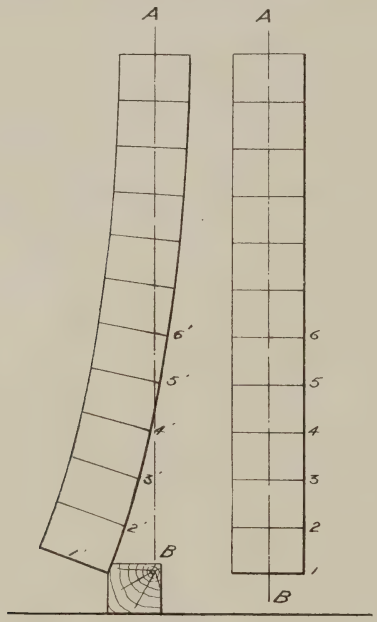



Fig. 2.

any frame produces a change in the deflection of all other frames. Moreover, since, as Lieutenant Hodges points out, the influence of the vertical diaphragms upon the deflections of the horizontal frames depends more on the design and workmanship of the connections of the diaphragms than upon their size and shape. This influence is a matter of great uncertainty. It is the writer's opinion that the influence of the vertical rigidity is less than is usually supposed.

Some general conclusions appear to be warranted, however. In a leaf in which the deflections of the frames are accurately calculated no frame need have a strength greater than that necessary to resist the pressure due to the depth. The upper frames, however, should

not be made too light, in consideration of shocks and other casual stresses, and for stiffness. It, perhaps, would be better to increase their intervals and the size of the individual frames. Since the effect of the support of the sill is to diminish the deflections of all frames, considerable economy of material could be effected if contact at the sill and a definite rigidity of the verticals could be insured. In practice it has, however, been impossible to insure contact at the sill, and the amount of the vertical rigidity is very indefinite and uncertain. Also the pressure at the sill is un-

Fig. 3.

certain, for even if there be contact it may not be such as to entirely relieve the lowest frame of its stress. The amount of this pressure depends upon the lengths of the leaves, as well as the total water pressure. If the leaves are too long, there will be no contact at the sill. For reasons pointed out by Lieutenant Hodges, contact at the post is more important than contact at the sill.

The conclusions of the preceding argument may be briefly stated as follows: Whenever two girders are rigidly connected by a diaphragm, the effect of the diaphragm is to transfer a portion of the load of the beam having the greater deflection to that having the

lesser deflection. If two beams connected by a diaphragm have unequal deflections, a decrease in the deflection of *either* from any extraneous cause produces through the influence of the diaphragm a decrease in the deflection of the other. The tendency of the diaphragm in every case is to equalize the deflections.

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## The First Regiment of Engineers at Waterloo

Abstract of a translation by H. E. Haferkorn, Librarian, Engineer School, from "Revue du Génie Militaire."

It has been commonly believed that the Old Guard was the last organization to retain its formation and oppose resistance to the English upon the stricken field of Waterloo. It should interest the Engineer troops of the United States Army, who have themselves proved their right to a place in the line of battle, to learn that the engineers of the French army should share that honor with the Old Guard. The following is quoted from an article by Capt. F. Simon, of the French engineers:

"Since attention has been once more attracted to this glorious detail of the heroic conduct of the French troops at Waterloo, it has seemed timely to recall to our comrades, or, rather, to make known to them another detail, which interests us more specially, and which deserves to be quoted, here more particularly so.

"Not far from the famous square formed by the Second Battalion of the First Regiment of Light Infantry (Chasseurs) of the Old Guard, whence has sprung the saying, 'The Guard dies, but does not surrender!' another square also was noticed for the firmness of their attitude: It was the First Battalion of the First Regiment of Engineers, attached to the Second Army Corps, under command of Commandant Rousseau.

" 'The seven companies of sappers of my battalion,' wrote this officer (the one of miners being detached at Valenciennes) 'was that day distributed among the divisions, except one, that of Captain Charve, which was designated as reserve and placed behind a fold of the ground, near the main road. Just at the moment when all the Corps were retiring in disorder, the remnants of five companies united themselves to the reserve company, as I had ordered in case of emergencies, and I organized a square, which by its appearance made them think, I believe, that it belonged to the Guard, because General Drouot announced to me that the

Emperor was coming to place himself in my square, but he did not appear.

"'Towards 8 or 9 o'clock at night a general of infantry arrived (a traitor, probably, it was said later), who gave the Battalion of Engineers an order to deploy themselves for battle. In the course of this unfortunate evolution, during which the subordinate companies executed a flank movement, the battalion was suddenly attacked and surrounded by a mass of light cavalry.

"'When their ammunition gave out, a part was obliged to surrender; the others made their retreat under command of Captain Vanneechout. All the infantry of the Army Corps which had been routed,' he wrote, 'was very far behind us, who were the last to leave the battlefield.'

"In a celebrated verse of the 'Messéniennes,' Casimir Delavigne has written:

> "'Parmi des tourbillons de flamme et de fumée
> O douleur! quel spectacle à mes yeux vient s'offrir:
> Le bataillon sacré, seul devant une armée,
> S'arrête pour mourir.'

"The historian henceforth better informed must answer: 'No, it was not alone.' Our sappers of the First Regiment of Engineers have the right to be proud of those ancestors who must share with the light infantry (Chasseurs) of the Old Guard the honor of having remained to the last moment on the battlefield, where the fortune of France was sinking."

# THE ENGINEER SCHOOL

*BY*

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*Instructor of Civil Engineering at the Engineer School*

A very curious fact has lately impressed itself upon the attention of the writer, and this fact is that outside of the Engineer Department very little is known about the Engineer School. Even its existence is unknown to many in high places, and there are not a few whose duties should require them to possess an intimate knowledge of its organization and work who have little more than a vague impression that it is a minor branch of the War College, or possibly that the latter is a branch of the Engineer School, or at any rate that there must be some relation existing between the two, because they are built upon the same reservation and appear to be parts of one general scheme. As a matter of fact, their purposes are widely different. Both are of great importance, and neither can be absorbed by the other without seriously crippling both. The general public ignorance on this subject is undoubtedly due to the habit acquired by all Government engineers of doing their duty to the best of their ability and then hiding the results deep in dusty and unattractive volumes of dry reports. Just as a man is blissfully unconscious of the existence of his digestive apparatus until it fails to work properly, and then suddenly develops an intense interest therein, so the country has been taught to accept the engineers of the War Department, both civil and military, as a part of the established order of things, and is prone to forget and overtax them until trouble results.

Space is lacking to attempt here a history of the Engineer School, but a brief reference to the past may be of interest in connection with an equally brief mention of the present. The future we will leave to speak for itself.

The following is quoted from William Duane's Military Dictionary, which was published in Philadelphia in 1810.

"During the administration of General Washington, the necessity of some military institute, or school, was frequently recommended; and in the administration that followed, the same policy was pursued: particularly at the period of raising the additional army in 1798. In the year 1792, military subjects were very much pressed upon Congress, as arising out of the state of the world, and the necessity of being prepared to ward against the dangers which might arise. In 1800, the subject of military defence was discussed, with increased zeal, and a very able and judicious report of the then secretary of war was laid before congress, in which it was proposed to establish a military academy to be divided into four general departments. 1. A fundamental school. 2. A school of artillerists and engineers. 3. A school of cavalry and infantry. 4. A naval school.

"The objects of this report fell to the ground. In 1802 (16 March), a law was passed, in which it was provided: *Sect.* 26. That the President of the United States is hereby authorised and empowered, when he shall deem it expedient, to organize and establish a corps of engineers, to consist of one engineer with the pay, rank, and emoluments of a major; two assistant engineers, with the pay, rank, and emoluments of captains; two other assistant engineers, with the pay, rank, and emoluments of first lieutenants; two other assistant engineers, with the pay, rank, and emoluments of second lieutenants; and ten cadets, with the pay of sixteen dollars per month, and two rations per day; and the President of the United States is, in like manner authorised, when he shall deem it proper, to make such promotions in the said corps, with a view to particular merit, and without regard to rank, so as not to exceed one colonel, one lieutenant-colonel, two majors, four captains, four first lieutenants, four second lieutenants, and so as that number of the whole corps shall, at no time, exceed twenty officers and cadets.

"Sec. 27. *And be it further enacted*, That the said corps when so organized, shall be stationed at West Point in the State of New York, and shall constitute a military academy; and the engineers, assistant engineers, and cadets of the said corps, shall be subject at all times, to do duty in such places, and on such service, as the President of the United States shall direct.

"Sec. 28. *And be it further enacted*, That the principal engineer, and in his absence the next in rank, shall have the superintendence of the said military academy, under the direction of the President of the United States; and the secretary of war is hereby authorised,

at the public expense, under such regulations as shall be directed by the President of the United States, to procure the necessary books, implements and apparatus for the use and benefit of the said institution."

Thus was established upon the banks of the Hudson the United States Military Academy, *the original Engineer School*, an institution admired and loved by all true Americans, a proper object of national pride, known and respected abroad as well as at home. For more than half a century this academy remained the Engineer School, and its superintendent was invariably an Engineer officer.

Referring again to the Military Dictionary, we read, "This school of engineers of the United States has been since augmented; and it is proposed to place it at Washington city." Although intended to be historical only, this statement seems to be prophetic; for the academy has indeed been augmented, and, after the lapse of a century, the Engineer School has at last been placed at Washington. The growth of the Military Academy has had an important bearing upon the Corps of Engineers; for it has gradually ceased to be an engineer school pure and simple.

The original scheme, as stated above, included a naval school, now permanently established at Annapolis; a school of cavalry and infantry, now the School of the Line at Fort Leavenworth; a school of artillerists, now fully organized and in successful operation at Fort Monroe for the Coast Artillery and at Fort Riley for the Field Artillery; and a fundamental school, now the Military Academy at West Point. It also included a school for engineers; and, curiously enough, this, the first of the proposed schools to be established, has apparently been lost sight of; for, owing to the recognized necessities of the service, the Engineer superintendents developed the academy along the lines of a fundamental school, to prepare officers for all branches of the service, sacrificing the special needs of engineering in order to obtain the greatest good to the Army. So about forty-two years ago—that is, immediately after the Civil War—it was discovered that the Military Academy had become more a fundamental school than a school for engineers, and, consequently, there was established quietly at Willets Point, N. Y. (now Fort Totten), a new school, which was the child of necessity and not created by specific legislative enactment, nor even recognized officially until 1885. This school was called The Engineer School of Application, which unwieldy name has since been shortened to the more appropriate name, Engineer School.

The writer has often been forcibly impressed, in reading old reports, with the fact that those who have preceded the present generation, and upon whom we sometimes fondly flatter ourselves we have improved, were men of brains and abilities. Their mental processes were generally more simple, direct and clear than our own, and they expressed their ideas quaintly, perhaps, but with the greatest power and perspicuity. Let us turn again to Duane and read the wisdom of a century ago. "The art of fortification is an art which stands in need of so many others, and whose object is so extensive, and its operations accompanied with so many various circumstances, that it is almost impossible for a man to make himself master of it by experience alone, even supposing him born with all the advantages of genius and disposition possible for the knowledge and practice of that important art." Now the art of fortification is but a part of the art of the modern military engineer. If, therefore, it was apparent a hundred years back that experience alone could not produce a military engineer, and that theoretical training was indispensable, why is the vital importance of an engineer school not appreciated to-day when the need for it is so much greater?

The most recent experiences of actual war prove that the value of the engineer is increasing as time goes on. We *must* have a corps of engineers, which, to be of value, must be efficient; which, to be efficient, must be specially educated in time of peace; which, to be specially educated, must be provided with educational facilities. In other words, the Engineer School is an absolutely indispensable institution.

There is another point to be considered: a corps of military engineers, to be educated in time of peace so as to be available in time of war, must be continuously maintained. To maintain an adequate corps in idleness or even in unproductive activity, when such a proceeding could be avoided, would be the height of extravagant folly. For this reason the Corps of Engineers has long been employed upon the improvement of rivers, harbors, canals and lighthouses: and this service has afforded the Corps such valuable experience in organizing and administering extensive engineering operations that, in addition to insuring economy in the disbursement of the vast sums appropriated for such civil works, the value of the Corps for extensive operations of military engineering has been actually enhanced. These considerations demand that the military engineer in this country shall be thoroughly educated in the

various branches of the art of the civil engineer; and this duty also devolves upon the Engineer School.

Here is another gem from Duane: "Experience teaches us, through the means of the errors we commit ourselves, what theory teaches us at the expense of others." From this it clearly follows that if our country ever foolishly abandons the Engineer School and sends out upon our important works young engineers lacking in theoretical training, the price of the education of these young engineers will be paid by the country for the errors which they will inevitably commit.

The writer has devoted considerable space to explaining the reasons for the existence of the Engineer School, but in view of certain recent experiences showing the widespread ignorance of the public in this connection, he has no apology to offer.

We have seen that the Engineer School is for the military engineer. Our students are therefore taken from the fundamental school, the Military Academy; and to explain the method of their selection we may turn once more to Duane. "The life of man being short, and opportunities of practice seldom happening, it is certain nothing less than a happy genius, a great share of theory, and intent application joined to experience, can make an engineer one day shine in his profession. From whence it follows, that less than the three first of those four qualities, should not be a recommendation for the reception of a young gentleman into a Corps of Engineers." It is reasonable to believe that the system of appointment of cadets to the Military Academy, combined with the tests to which candidates are subjected before acceptance and throughout the four years' course of instruction, insures that all graduates will be above the average of intelligence and general ability. Is it not equally reasonable to conclude that among those who specially distinguish themselves in a competitive test extending through four years, we should be *most likely* to discover those members of each class who possess a most promising combination of "a happy genius, a great share of theory, and intent application?" For this reason, the cadets who graduate near the head of a class are habitually selected for assignment to the engineers. It can not be claimed that this method of selection gives us always the ablest potential engineers in a class nor does it necessarily take away from the other branches of the service the men best suited for them; but we must admit that the human mind would

be put to it to devise a system more likely in the long run to give us suitable men for developing into successful engineers.

Having selected a number of young engineers possessing, presumably, the three qualities above named, we proceed to add to their "share of theory" and to give them the required experience. For a year after their graduation they are assigned to stations where important engineering operations are in progress, in order that their minds may be refreshed and rested after their four years of "intent application," and may be interested and stimulated by contact with the world's work. During this year they are required to read standard books on the theory of the work with which they are associated and to note the practical application as therein made, taking such active part as may seem proper and permissible. Then they take a thirteen months' course at the Engineer School, after which they spend another year at Fort Leavenworth, where they acquire that part of their education which can be learned only by contact with the troops of other branches of the service.

At present the Engineer School consists of three departments: Civil Engineering, Military Engineering, and Electrical and Mechanical Engineering. The last number of the PROFESSIONAL MEMOIRS contained a memorandum outlining the course of the last-named department. We have already exceeded our proper limit of space for this article, and so we will close with a brief statement of the curriculum of the School. In future numbers of the MEMOIRS it is planned to discuss more fully the various courses which are here named only.

*Department of Civil Engineering.*

Surveying,
Military Topography,
Military Reconnaissance,
Roads and Railroads,
Water Supply,
Sewage,
Cements, Mortars, Concretes,
Masonry and Foundations,
Roofs and Bridges,
Building Construction,
Heating and Ventilation,
River and Harbor Improvements, Canals,
Contracts, Specifications, Estimates and Accounts, Construction Plant,
Lighthouses and other Aids to Navigation.

*Department of Military Engineering.*

Army Regulations,
Administration,
Guard Duty,
Field Service Regulations,
Drill Regulations,
Ponton Drill,
Small Arms Firing Regulations,
Tactics and Logistics,
Minor Tactics,
Military Law,
International Law,
Military Hygiene,
Hippology,
Field Fortifications,
Permanent Fortifications,
Semipermanent Fortifications,
Seacoast Defense,
Ordnance, Armor, Explosives,
War Ships and Sea Power,
Organization and Equipment of Troops,
Field Duties of Engineer Officers,
Sieges and Campaigns,
Field Engineering.

*Department of Electrical and Mechanical Engineering.*

Direct Current and Alternating Current Machinery,
Storage Batteries,
Transmission of Energy and Intelligence,
Electric Lamps,
Steam Engines and Boilers,
Gas and Oil Engines.

*Practical Work.*

Laboratory Work in Connection with All Above.

Field Astronomy,
Military Photography,
Map Reproduction,
Military Reconnaissance and Sketching,
Hydrographic Surveying,
Topographic Surveying.

The Engineer School is not devoted exclusively to the education of commissioned officers. The enlisted men of the Corps of Engineers as well must be trained for their field duties. An engineer company is of little value as such unless it is a company of *engineers*. We all remember the story of the disabled locomotive which was found in a ditch by the Union troops during the Civil War. A soldier stepped from the ranks and offered to repair it. Naturally, doubt was expressed as to his ability; whereupon he explained that as he had built the locomotive he was also able to repair it; and he successfully accomplished the job. This incident illustrates the value to soldiers of training in the mechanical trades. In order that our men may rise to emergencies in the field, the Trades School is established at the Engineer School. In it the men are trained in carpentry, blacksmithing, plumbing and pipe fitting, masonry, draughting, electrical work, photography and map reproduction. This branch of the Engineer School will be more fully described hereafter.

## Selected Articles of Engineering Interest

*Bridges.*

Substructure of Piscataquis Bridge and analysis of concrete work, by G. A. Hersey, with discussion. Paper 1085. Trans. Am. Soc. of Civil Engrs., v. 61, pp. 377-386. With plates and 1 table.

*Cement and concrete.*

Bonding of new to old concrete, by E. P. Goodrich. Engrg.-Contr., Feb. 24, '09, p. 145; Mar. 3, '09, pp. 159-162, with diagrs. and table.

Cast reinforced concrete piles, by S. E. Thompson and Benj. Fox, with discussion. Jour. Ass'n, Engrg. Soc., Jan., 1909, pp. 1-23. With pl., fig., tables.

Diagrams for reinforced concrete beams, by H. C. Schermerhorn. Engrg. Rec., March 6, 1909, pp. 263-264, with fold. pl.

Dropping concrete into place from a height. (Letters to the editor.) Engrg. Rec., March 6, '09, pp. 279-280, 1 illus.

Government tries concrete piling in river improvement. "Concrete," March, 1909, p. 51.

Making concrete watertight. (Editorial.) Engrg. Rec., Mar. 6, 1909, p. 253.

Old and new concrete used in ancient Florida fortification. "Concrete," March, 1909, p. 40, 1 illus.

Some of the uses in which concrete is taking the place of timber. "Concrete," March, 1909, p. 67.

Why concrete disintegrates in sea water. "Cement Age," Jan., 1909, p. 53.

*Cost data.*

A simple cost-finding system for complex situation, by J. Sturgess. Engrg. Mag., March, 1909, pp. 940-948. With tables.

*Dams.*

Concrete dam under construction across the Connecticut River. "Concrete," March, 1909, pp. 72-73, illus.

Experiments with rubber models to determine stresses in masonry dams. Engrg. Rec., March 6, '09, pp. 268-270, with diagrs.

The Isna barrage across the Nile. Scient. Am., March 6, '09, pp. 189-190. Illus.

Method and cost of constructing a concrete core wall for wing dam. Engrg.-Contr., March 10, '09, p. 183.

Recent practice in hydraulic-fill dam construction, by J. D. Schuyler, with discussion. Paper 1043. Trans. Am. Soc. Civil Engrs., v. 58, pp. 196-277. With diagr. and pl.; same, discussion by J. M. Howells and J. D. Schuyler. Paper 1063, v. 60, pp. 101-109.

*Earthquakes and high buildings.*

Effect of earthquake shocks on high buildings, by R. S. Chew, with discussion. Paper 1082. Trans. Am. Soc. Civil Engrs., v. 61, pp. 238-252. With diagrs.

*Engineering.*

Suggestions for the conduct of engineering work in the tropics, by Robt. Burgess. Engrg. News, March 11, '09, pp. 260-264, with diagrs. and illus.

*Excavation.*

Method and cost of trimming the side of a rock excavation. Engrg.-Contr., March 3, '09, p. 166.

*Floods.*

The flood of March, 1907, in the Sacraemnto and Joaquin River basins, Cal., by W. B. Clapp, E. C. Murphy and W. F. Martin, with discussion. Paper 1084. Trans. Am. Soc. Civil Engrs., v. 61, pp. 281-376. With diagrs. and tables.

*Hydro-electric power plants.*

The hydro-electric developments of the Nevada-Cal. Power Co. Engrg. Rec., March 6, '09, pp. 256-258. With illus., diagrs.

The M'Call's Ferry hydro-electric power plant, by Wm. Allen. Scient. Am., March 13, '09, pp. 203-205, illus.

*Locks.*

A movable lock for inclined canals. Scient. Am., March 6, '09, pp. 184-185, illus.

*Masonry.*

The effect of temperature changes on masonry, by C. S. Gowen, with discussion. Paper 1087. Trans. Am. Soc. Civil Engrs, v. 61, pp. 399-437. With pl., diagrs.

*Materials.*

More evidence of the longevity of creosote piles. (Letter to the editor.) By W. G. Arn. Engrg. News, March 11, '09, p. 277

The strength and absorption of brick, and a comparison between different methods of determining absorption. Engrg. News, Mar. 11, '09, pp. 273-274.

*Panama Canal.*

The foundations for the Gatun locks. (Editorial.) Review of Maj. Chester Harding's report. Engrg. Rec., Jan. 2, '09, pp. 7-8, with illus. and diagrs.

Panama sea-level arguments. (Letter to the editor.) By H. G. Granger. Engrg. News, March 11, '09, p. 277.

A sea-level canal at Panama. A study of its desirability and feasibility, by H. G. Granger. Bull. Am. Inst. of Mining Engrs., Jan., 1909, pp. 1-37. Illus., etc.

Testimony of Col. Geo. W. Goethals, Chief Engr. of the Panama Canal, before the House committee on appropriations. Engrg. News, March 11, '09, pp. 280-281.

*River Engineering.*

Caving banks, by B. M. Harrod. Jour. Assn. of Engrg. Soc., Jan., 1909, pp. 36-41.

A defence of the present system of improvements on the Kanawha River, by F. W. Altstaetter, Capt., Corps of Engrs. Engrg. Rec., Feb. 13, '09, pp. 172-175. With chart and tables.

Federal investigation of water resources. Engrg. Rec., March 6, '09, p. 273.

The improvement of the Ohio River for navigation. (Editorial.) Engrg. News, Oct. 8, '08, pp. 381-383, with chart and table.

The improvement of the Ohio River, by Wm. L. Sibert, Maj., Corps of Engrs., Proc. Am. Soc. Civil Engrs., Oct., 1908, illus.

Improvement of the upper Mississippi River, by C. McD. Townend, Lt.-Col., Corps of Engrs., with discussion by C. F. Loweth, Majs. Judson, Rees, Col. Chittenden, etc. Jour. West. Soc. of Engrs., Feb., 1909, pp. 26-72. With 12 pl. (10 fold.), and tables.

Note on the improvement of the Mississippi River, by W. G. Price, with discussion. Paper 1073. Trans. Am. Soc. Civil Engrs. v. 60, pp. 339-344.

Permanent improvement of the Ohio River, by P. S. Bond, Capt. Corps of Engrs. Engrg. Rec., Dec. 26, 1908; Jan. 2, 9, 16, and 23, 1909. Illus. and diagrs.

Proposed reservoir system in Ohio River basin, by H. C. Newcomer, Maj., Corps of Engrs. Engrg. News, Oct. 8, '08, pp. 376-380. With diagrs., charts and tables.

Proposed reservoir system in the Ohio River basin, by M. O. Leighton. (Reply to an article by Maj. H. C. Newcomer), Engrg. News, Nov. 5, 1908, pp. 504-507.

Forests and reservoirs in their relation to stream flow with particular reference to navigable rivers, by H. M. Chittenden, Lt.-Col., Corps of Engineers, Proc. Am. Soc. Civil Engrs., Sept., 1908, illus.; Discussion, Nov., 1908.

Report of the Pennsylvania water supply commission: Forests, stream, flow and flow control. Engrg. News, Nov. 19, '08, pp. 555-556.

*Sea walls.*

Sea wall of concrete. "Concrete," March, 1909, p. 77 (illus.).

# Editorial Notes

Since the issue of the first number of the Professional Memoirs, several letters have been received which indicate that explanations of certain points may be of value.

The form and size of the magazine were determined after examination of publications of engineering associations, both in this country and abroad; and were made the same as those of the "Occasional Papers" of the Engineer School, in order that all School publications might be bound uniformly, if desired.

The field of the Professional Memoirs is too wide to be covered by any one number, or even by several numbers. We believe the value of the magazine will be more apparent with each succeeding issue. It is primarily a medium for the exchange of ideas among the Government engineers, and it is desirable that such exchange shall be direct; that is, that each engineer shall present his own views in his own language. Therefore, let each man send in whatever seems to him to be of sufficient interest and value for publication. Records and clear explanations of failures, descriptions of successful work, cost data, useful formulas, interesting historical bits—in short, the very things that each man finds necessary to assist and guide himself. Each paper should be clear, brief, and to the point, rather than exhaustive. A moderate number of good illustrations is desirable. Drawings in black and white are preferred to blue prints, as the latter must be traced before lithographs can be made.

Helpful suggestions are always in order, and the many already received are gratefully appreciated.

A most gratifying increase in our list of subscribers has taken place. The increase in our advertising section is apparent. We have reached a point now where success seems assured.

The two drawings published in the article on Manitowoc Harbor were traced, photographed and lithographed in the Trades School for enlisted men. This important branch of the Engineer School will be more fully described in the future.

# PROFESSIONAL MEMOIRS

*ENGINEER BUREAU, UNITED STATES ARMY*

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WOLSEY:

"Might is not all.
Shrewd thinking now wins further than stout blows,
The old arms rust, but from the new forged steel
Come flashings bright with thought. I pray your Grace
Forget that here are colleges and clerks;
Only remember here be men who think,
And even as the brain is master of the hand,
The master of the Nation's task is here.
Here let us build, but not with stones alone;
Let 's build with courage, faith, and enterprise,
With daring, and a challenge to the unknown,
And most with honesty. Let 's build a house
Wherein by subtle spirit — alchemy
Men may transform the wise high thoughts of old
To new and golden deeds. Then shall we build
As I have dreamed we built"——

*Oxford Historical Pageant, 1907.*

# Repairs to Dam at Lock A, Cumberland River

*BY*

Major William W. Harts
*Corps of Engineers*

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Considerable differences of opinion have arisen from time to time as to the best type of dam to be used in streams where fixed dams are applicable. Concrete seems now to be replacing timber cribs and stone masonry and is admirably suited to many localities. There will doubtless be many occasions, however, when the cheapness of lumber and the proximity of rock, together with poor natural foundations, may make timber cribs desirable. The section of dam most suitable will then be a matter of study and selection.

The two types that have been most used are the step dam and the slope dam, so called from the shape of their downstream faces. The advantages of the step dam are that it breaks the fall of the water, causing its energy to be taken up partly in shock on the structure and partly in eddies, and that it is easy of construction. It is open to the disadvantage of being subject to damage by heavy drift, but in such cases repairs are easily made at low water. The slope dam is thought to pass floods more easily and to cause less erosion of the river bottom and banks.

The advocates of the latter type have been somewhat in a quandary as to the proper inclination to give the downstream face. It is easily seen that the steeper this face is made the greater will be the disturbance caused by the backlash at the toe. Furthermore, the shape of the wave at the foot of the dam, in both the step and the slope design, sometimes makes it impossible for drift to escape at certain intermediate stages, and logs and trees are then tossed about in the backlash, assaulting the timberwork of the dam and often doing considerable injury before the stage changes sufficiently to enable them to pass downstream.

It was found by Col. W. E. Merrill, Corps of Engineers, in his Muskingum River work, that a slope steeper than 4 on 1 would not easily shed drift. This conclusion seems to have been corroborated by the experience of the officials of the Ponts et Chaussées in France. This

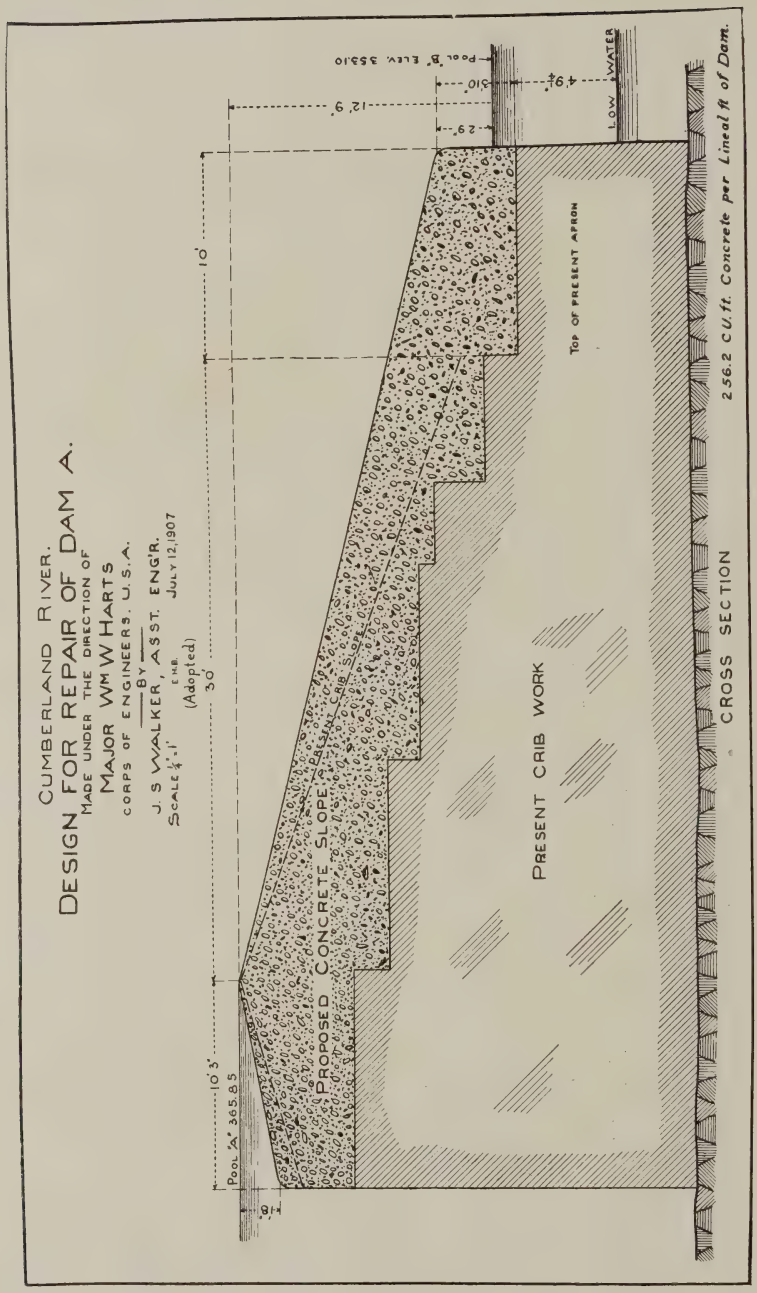
CUMBERLAND RIVER.
DESIGN FOR REPAIR OF DAM A.
MADE UNDER THE DIRECTION OF
MAJOR WM W HARTS
CORPS OF ENGINEERS. U.S.A.
BY
J. S WALKER, ASST. ENG'R.
SCALE 1/4" = 1'
JULY 12, 1907
(Adopted)
30'
10'
10' 3"
Pool A 365.85
18"
PROPOSED CONCRETE SLOPE
PRESENT CRIB WORK
TOP OF PRESENT APRON
LOW WATER
Pool B Elev. 355.10
4'9½"
5'10"
12' 9"
2' 9"
CROSS SECTION
256.2 C.U.ft. Concrete per Lineal ft of Dam.

Fig. 1.

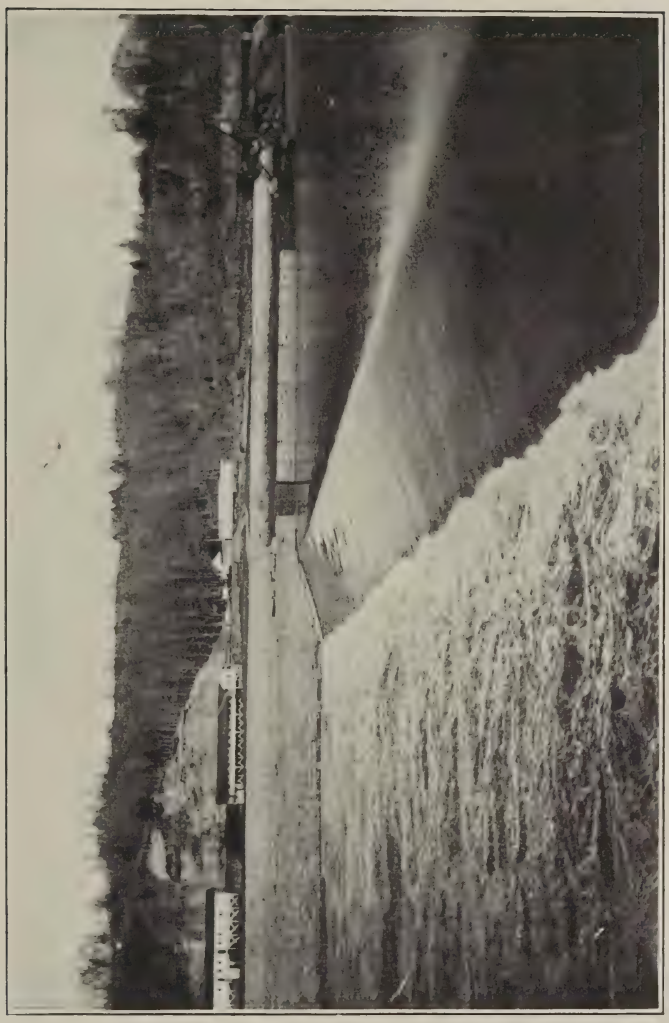

Fig. 2.

flatter downstream slope has the additional advantage of removing the point of greatest scour farther below the toe, thus adding to the safety of the dam.

The dam at Lock A, Cumberland River (Fig. 1), is a timber-crib structure, filled with rock. It was originally built with a downstream face having a slope of about 2½ on 1 and was provided with a 10-foot apron. Its top had been damaged in several high waters by trees and logs which were turned over and over in the backlash, unable to escape, occasionally for days at a time, until some apprehension had arisen regarding the safety of the structure.

In making repairs it was determined to adopt the 4 to 1 slope, heretofore found effective in preventing trouble from this source, and to cover the top surface with concrete rather than with timber; a slope dam lending itself with peculiar facility to this kind of repairs. Accordingly plans embodying these changes were prepared, and the work was carried out in the low-water season of 1908. (Fig. 1.)

A photograph (Fig. 2) of the completed dam at a high stage of river shows the success of this design. Its performance during the recent unusually high water has been very satisfactory.

## "Military Instructions for Officers"*

The night being the most proper time to march to the attack of a post, you should set out soon enough to be ready to make the attack an hour or two before day. Care must be taken that it is not moon-light when you propose making the attack; the soldiers ought to march two and two, with the least noise possible, especially when passing between the enemies centries: you must likewise recommend to them, neither to speak, spit, or smoke. The detachments must get as opposite as possible to the salient angles of the intrenchment, as it is probable that they will be the least defended by the enemy's musketry. * * *

If the post which you want to carry is a redoubt with a dry ditch and parapet of earth, your two first ranks must have spades and pick-axes, with their arms slung, and on the signal being given, jump into the ditch together; I say together, because it ought to be a general maxim in attacking a post, to strike all at once. When the first rank have jumped down, the second must stop a moment, that they may not fall upon the shoulders or bayonets of the first. The two first ranks having got into the ditch, they should immediately run to sap the angles of the scarp, and the parapet of the redoubt, to facilitate the mounting of the rest of the party; the leaders of each division should observe at the same time, that the soldiers who remain armed with their firelocks, and who have likewise leaped into the ditch, do not interrupt those who are demolishing the scarp of the redoubt, but protect them by presenting their bayonets to the right and left, and be ready to repulse any of the enemy that happen to be placed in the ditch.

If the parapet is fraised, they should break as many of the fraises with hatchets as is necessary to let the men pass. When the breach is made, the workers should drop their working tools, and taking their arms from the slings, mount up with fixed bayonets, and rush upon the enemy huzzaing.

* Being an extract from "Military Instructions for Officers Detached in the Field," by Roger Stevenson, Esq., published by R. Aitken, Philadelphia, 1775.

# Proposed Plan for the Engineer Department in Case of War With a First-Class Power

*BY*

MAJOR J. E. KUHN
*Corps of Engineers*

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The lessons of the Spanish-American War are still fresh in the memories of most of us, and it must be a matter of gratification that these lessons have borne some fruit. While much still remains to be done to overcome the glaring imperfections of our military system as revealed on that occasion, much has also been accomplished as a result thereof. Among these results may be mentioned an increase and a better organization of our regular establishment, the creation of a general staff, the adoption of a Field Service Regulations, the publication in orders of details of arms and equipment, legislation for the improvement of the militia, and providing contingently for its use as a national force in time of war, and a more liberal attitude on the part of the nation toward recognizing and providing for its military necessities. In the army itself there is manifested an earnestness and sincerity of purpose that augur well for the future and justify the hope that the lamentable experiences of 1898 will not be repeated. While our political system will ever forbid that thorough preparation for war possible only with large standing armies, we surely can and should plan in advance, and in detail, everything relating to organization and equipment, so that these matters will be thoroughly understood by all. In this way only can we expect to avoid a part, at least, of the confusion and turmoil incident to mobilizing a field army capable of defending our country and of maintaining its honor. Any war in which the United States may engage will surely be a just war, and one that will arouse the patriotism and sense of self-sacrifice of the people—a popular war, so to speak—and it is certain that there will be no lack of men ready to respond to the call to arms. The problem, then, is not one of numbers, but of organization, equipment, and training in the quickest and most effective manner. Since 1898 we have made true progress in this direction, and this should serve as an encouragement to persistent and continued efforts to do everything possible toward preparing the nation

for war. The fact that any field army must be largely made up of unorganized volunteers is a permanent and inevitable handicap, for which there is no remedy, but which makes it all the more important that every detail of organization, equipment, and training be thoroughly planned and decided upon in advance. In what follows it is proposed to discuss, briefly, the possibilities of an adequate engineer service by the Corps of Engineers in case of war with a first-class power, having special reference to the larger tactical units, and to the service of the lines of communications, based rather upon existing conditions than upon theories.

Since my subject assumes a war with a first-class power, it is evident that a large field army will be called into being, but just how large is problematical. Among the many defects of our existing military system is the uncertainty which must always confront those responsible for organizing and equipping a field army as to just what will be required at the outset, and the necessity for waiting for developments, to a greater or lesser degree.

But, whatever the size of the field army to be created in the first instance, it must, under the condition assumed, greatly exceed the maximum authorized strength of the Regular Army, even if it were possible to concentrate the latter into one body in any reasonable time. For the purpose of this paper it will be assumed that the field army will consist of not less than twenty divisions, or about 350,000 combatant troops, organized as prescribed in the Field Service Regulations.

An adequate engineer service for an army of this size will call for the following:

1. Twenty divisional engineer battalions.
2. Twenty divisional engineer staff officers.
3. Reserve engineer troops for duty on the lines of communications and at engineer depots.
4. Engineer staff officers for the staffs of corps and army commanders, the number depending upon the organization of the larger army units.

With respect to the divisional engineer battalions it can not be too strongly insisted that these must form a necessary integral part of the division, just as much as the divisional artillery or cavalry, and that they should not be detached from their divisions, save for exceptional and urgent reasons. If properly employed, the divisional engineer battalions can and will render valuable services in combat, on the march, and while in camp or cantonment, and their activities should be limited, normally, to the immediate sphere of operations of the divisions to which they belong.

A division of troops of the strength contemplated by our Field Service

Regulations will cover a front of from 2 to 4 miles and occupy a depth of equal or greater extent; that is to say, the division will occupy from 4 to 8 square miles of ground. The special engineering works likely to be called for in so large an area, whether in the preparation of defensive positions, interior communications, in surveying and mapping, or in the construction of camp features designed for the comfort and convenience of the troops, are so extensive and important as to give the fullest occupation to the single engineer battalion attached to a division. The proportion of engineer troops, as laid down in the Field Service Regulations, constitutes about one-thirtieth of the division, a proportion not at all too large, in view of the amount and character of the engineering work which is likely to be encountered in field operations. In the Japanese army, during the Russo-Japanese War, the proportion of engineer troops was about one-twentieth, and the experience there gained indicated that this proportion was none too large. The strategical movements of the Japanese were certainly slow and are attributable, in part at least, to their inability to keep their armies supplied, over the wretched roads of Manchuria, a condition which could have been materially bettered by a better use and by a larger number of engineer troops. The prediction is also ventured that in future field battles there will be occasions when operations similar to sieges will be required in the attack and defense of positions and for which engineer troops will be in demand. The works executed by both Russians and Japanese at certain positions closely resembled siege operations and involved sapping and mining. It is to be assumed, therefore, that in any organization of a field army each division will have its complete engineer battalion, consisting of three pioneer companies with their mounted sections and one pontonier company with the allotted bridge train.

With respect to the reserve engineer troops, it does not appear that any special provision has been made for them in the Field Service Regulations, but their necessity is none the less apparent, if the service of the lines of communications is to be properly maintained and divisional commanders are to retain control of the divisional battalions. The number of such reserve engineer troops required for the assumed field army would vary with the circumstances of the campaign, more especially with the number of armies organized and the number of lines of communications. Probably three battalions would suffice, in the first instance, to supply an adequate reserve to be assigned to the different army commands.

Having now formed an approximate estimate of the amount of engineer troops to be supplied for the field army, it remains to consider how they can best be provided. This question is intimately connected with the

entire subject of army organization, concerning which it is not too much to say that its present condition, so far as revealed by existing laws, is still somewhat chaotic. This condition of affairs affects not only the engineer units, but other arms of the service as well; and, until remedied by suitable legislation, there is little chance of our being able to put into the field a large army rationally organized in all its various departments. While the Field Service Regulations cover the subject of army organization fairly satisfactorily, it is a fact that there is as yet no legislation whereby such organization can be effectively carried out. That this matter has received the attention of the War Department is evidenced by the pending bill in Congress to provide for raising a volunteer army of the United States in time of actual or threatened war—a most excellent bill, and one which should unquestionably be placed on our statute books. Until this is done, existing laws must govern all measures looking to the creation of a field army, or we must defer preparations, pending adequate legislation coincident with or subsequent to the outbreak of war, as was done in 1898. The fatuity of the latter course must be evident to every thinking man, in these days of rapid mobilization and concentration of troops by nations with large standing armies, in which the problems of organization have already been fully worked out, and which can proceed at once with their strategy and logistics, while we would be still pondering the very elements of organization. It is of the highest importance, therefore, that all questions as to ways and means for creating a volunteer army should be most carefully and thoroughly planned in advance, and the necessary legislation passed for putting these plans into effect with the least possible delay when the emergency arises.

Returning to the subject of the organization of engineer troops: How can we best obtain, equip, and train the twenty-three battalions deemed necessary for the assumed field army? Of the three regular battalions it may be assumed that but two will be available for assignment to the field army, the third battalion being on foreign service in the Philippines and the Hawaiian Islands. This will leave twenty-one battalions to be supplied from other sources, either militia or volunteers. Any plan of expansion for converting the regular engineer battalions into twenty-three would be carrying the process of dilution so far as to result only in the loss of the trained units without corresponding benefits, and need not be further considered. Any such plan of expansion would, moreover, be dependent upon legislation, pending which there would be loss of valuable time. It is apparent, therefore, that we must look to the organized militia and to the volunteers if we are to provide an adequate engineer service for the field army. At the first glance it might appear that the

creation of volunteer organizations of technical troops would be especially difficult and unsatisfactory. So far as engineer troops are concerned, the case is not so hopeless, and it may be accepted, at the outset, that there is no dearth of excellent material available for forming volunteer engineer organizations. The many large industrial enterprises in the United States, the vast business and transportation corporations, have created an army of men whose daily occupation lies in the varied fields of engineering. These men are characterized by intelligence, capability, and resourcefulness, and their training for their several civil occupations fits them, in an eminent degree, to meeting the special requirements of engineer troops, whether as officers or enlisted men. Engineering organization in the conduct of large enterprises is, moreover, not unlike military organization and involves subordination and obedience to authority in much the same way. Men drawn from the many fields of civil engineering will therefore readily adapt themselves to military discipline and quickly learn the duties and the spirit of the soldier. Much of the work of the civil engineer also necessitates field life, with abundant experience in camping and roughing it, all valuable qualities.

In any call for engineer troops there need be little fear but that an abundant supply of most excellent material will offer itself, and it only remains to consider how this material can be most quickly organized, equipped and trained.

Unfortunately, existing laws and orders bearing upon the organized militia and the volunteer army make no definite provision for securing the proper quota of engineer troops necessary for the army organization laid down in the Field Service Regulations, nor has any definite plan been devised, so far as is known, for meeting this contingency. The present organic law providing for a temporary increase in the military establishment in time of war is the act of Congress approved April 22, 1898, and must necessarily govern all measures for recruiting a volunteer army, until repealed or amended. This law provides, *inter alia*, for the enlistment of organized militia units volunteering as a body, and it is therefore pertinent to inquire what might reasonably be expected in this particular for engineer troops.

The latest roster of the organized militia discloses the fact that there are very few organized militia engineer units. New York has one regiment of ten companies, with two additional companies in formation; Ohio has one battalion of four companies; while five other States have each only a company or detachment. Even if it be assumed that all the foregoing organized militia units should become available, either through volunteering in a body, or through the contingencies being such as to

authorize their being called into service as militia, it would still leave a large deficiency in the needed number of engineer units while those so obtained would not conform in their organization to that prescribed in the Field Service Regulations. It is doubtful, therefore, whether much dependence should be placed upon the organized militia as a source of supply for engineer units. This is not intended as a reflection upon these militia engineer units, for some of them, notably the Ohio battalion and the New York regiment, are fairly well organized and instructed as pioneers and imbued with commendable zeal and spirit. At the best, not more than four imperfectly organized battalions could be obtained from the militia at present, three from New York and one from Ohio. Another source for engineer units under existing law is the act of May 11, 1898, providing for a volunteer brigade of engineers to consist of three regiments of not to exceed 3,000 men, all told, to be recruited from the nation at large, under such rules and regulations, including the appointment of officers, as may be prescribed by the Secretary of War, and authorizing not to exceed three officers from the Corps of Engineers to hold commissions at any one time in one regiment. This act is still in force, and will afford the necessary warrant of law for the immediate organization of a part of the engineer units required. The limitation as to number will, however, prevent the attainment of three battalions, or even two, of full war strength for each regiment. The provision for recruiting engineer troops from the nation at large is a most excellent one, and it would be well if the principle could be extended so as to apply to all technical troops specified in our army organization. The three engineer regiments recruited under the above law in 1898 were composed of a high order of material, and the rolls of their officers embraced the names of many men of eminent distinction in the profession of engineering.

The volunteer engineer brigade can be made to furnish nine battalions, each of but little more than half the prescribed war strength; and, although brigade and regimental formations for engineer troops are not contemplated by the Field Service Regulations, it seems advisable to have recourse to the law, in view of the manner in which the brigade is recruited and officers appointed, and the fact that provision is made for the assignment of three officers of the Corps of Engineers in each regiment.

Still another and the final source for the needed engineer units is the law of April 22, 1898, providing for the organization of a volunteer army. Under this law the Secretary of War "shall prescribe such rules and regulations * * * for the purpose of examining, organizing and receiving into service the men called for." Under this law the War Department would appear to have the necessary authority, not only to

prescribe what numbers of volunteers should be furnished by each State and Territory under its apportionment, but also the proportion of the different arms of the service. Unless the proportions of the different arms of the service be controlled by the War Department, it will be hopeless to expect any proper organization for the larger units from the volunteers, and it must be presumed that in so important a matter the several States and Territories will be required to furnish volunteers to the different arms of the service in proper proportions for the organization of the field army, and that provision will be made for the needed engineer troops at the same time as for the infantry, cavalry, artillery, and all other special troops.

An unfortunate feature of the law of April 22, 1898, is the fact that appointments of officers are left to the governors of the States and that but one officer from the Regular Army may, with the consent of the President, be appointed to each regiment. In order to secure the advantage of having an officer of the Corps of Engineers detailed with State volunteer engineers, it will be necessary to have recourse to a regimental organization.

The law of April 22, 1898, also authorizes the Secretary of War to organize units having special qualifications from the nation at large, not to exceed 3,000 men, all told, the officers to be appointed by the Secretary of War. In the Spanish-American War recourse was had to this provision of the law for the organization of three regiments of United States volunteer cavalry — the so-called "Rough Riders." This law is still applicable and may be invoked for the organization of 3,000 volunteers from the nation at large for any purpose deemed best by the War Department, including volunteer engineer regiments or battalions, and it will be assumed that three engineer battalions would be authorized from this source, leaving the remainder of the special contingent available for other special troops.

Recapitulating now all possible sources from which the personnel for engineer units may be drawn under existing law, we have the following:

1. Three regular battalions, of which two will probably be immediately available.
2. Four battalions of the organized militia, contingently available.
3. Nine battalions of the engineer brigade, each battalion of but little more than half the prescribed war strength.
4. Three battalions recruited from the special contingent of 3,000 men authorized by the act of April 22, 1898.
5. State volunteer engineer regiments as may be called for by the War Department.

This motley and incongruous array of sources covers all possible means

for the organization of engineer troops under existing law, and it is needless to point out that they are far from satisfactory as regards obtaining an adequate number of engineer units uniformly organized and officered.

Half a loaf is better than no bread, and we must make the best of the situation as we find it, until something better presents itself. What, then, can be done toward securing a reasonably adequate engineer service for the field army under existing conditions? Among the several solutions possible, the following is suggested as being as good as any other:

1. Coincident with the call for volunteers, appoint three officers of the Corps of Engineers, with volunteer rank, for each regiment of the engineer brigade, with orders to recruit the same to authorized strength from assigned districts of the country.

2. Appoint three officers of the Corps of Engineers, with volunteer rank, each to recruit one battalion of engineers from an assigned district under the provisions of the act of April 22, 1898, authorizing a special contingent of 3,000 volunteers from the nation at large.

3. Include in the call for State volunteers three regiments of engineer troops, to be assigned to the most populous States — such as New York, Pennsylvania, and Illinois — the services of one officer of the Corps of Engineers, with volunteer rank being offered for each regiment, to the governors of the States, with a view to his appointment as colonel, lieutenant-colonel, or major, to assist in the organization of the regiments. Such appointment is of course voluntary with the governor, but it may reasonably be expected that he will not be averse to availing himself of the offer. The volunteer organizations named, with the two regular battalions assumed to be available, will supply twenty-three battalions. Should sufficient engineer units be obtainable from the organized militia, it will be possible to reduce the number of State volunteer regiments from three to two, and it is presumed that the War Department will have early advice as to this contingency.

With the exception of the battalions of the engineer brigade, whose numerical strength is limited by law, all other engineer battalions can be made to conform to the organization prescribed in the Field Service Regulations, by suitable orders from the War Department. In order to have the companies of the engineer brigade approximate the strength of the regular engineer companies, it might be well to organize its battalions into three companies instead of four, two being pioneers and one pontoniers.

If the above programme be carried out, it will call for the services of 15 officers of the Corps of Engineers for duty with the engineer field units, which is about all that can be assigned under existing law. Besides

the officers of the Corps on duty with troops, there will be required 20 divisional staff officers of engineers, and an indeterminate number for the larger units, depending upon Corps and army organizations. If we assume the 20 divisions to be organized into 7 army corps and 3 armies, 10 staff officers of engineers, in addition to the 20 staff officers for divisions, will be required, making a total of 30, all told, for staff duty. While it is deemed desirable that all engineer staff officers be supplied from the Corps of Engineers, it appears doubtful whether so many as 30, in addition to the 15 required for service with volunteer engineer troops, can be drawn from the present strength of the Corps. Certain responsible duties devolving upon the Corps of Engineers by law must go on in war, as well as peace, and can not at present be transferred to other hands. A serious defect of the existing law relating to the organization of a volunteer army is the fact that no provision is made for replacing officers withdrawn from the various staff departments for duty in the field, and this defect bears with special hardness upon the Engineer Department. It is hardly necessary to state that every effort would be made to supply all possible officers required for an adequate engineer service for the field army, by doubling up duties, and calling in every available officer, but, with the best efforts, it is not believed that as many as 45 officers could be furnished under existing conditions. The Corps of Engineers has an authorized strength of 189 officers, of which 57 are required to officer the 3 regular battalions. With 45 more deducted, but 87 would be left to administer to the needs of the seacoast defenses, the various civil works, including the Panama Canal, and a number of other duties. The requirements of our seacoast defenses alone will be particularly exacting in time of actual or threatened war, and will call for great exertions on the part of a considerable number of engineer officers. It will therefore be necessary to draw upon other sources for a part at least of the required engineer staff officers, and these can best be obtained by appointments, with increased volunteer rank of officers, from other branches of the army, as was done in the Spanish-American War.

The foregoing observations are based entirely upon the supposition that existing laws still govern the creation of a field army in time of war, and they serve to show some of the serious defects of organization under which we at present labor.

In strong contrast with the present imperfect laws governing the formation of a volunteer army, is the pending bill in Congress. This bill provides, *inter alia*, for the appointment of volunteers among the States, not only by numbers, but also by arms of the service. Appointments of officers are placed under the supervision of the War Department, and the

number of officers from the regular establishment that may serve with each volunteer unit is prescribed.

Finally, and most important, provision is made for replacing, by volunteers, all regular officers withdrawn for volunteer service.

With such a law in force provision for an adequate engineer personnel becomes a comparatively simple matter. All that will be needed is to include the requisite number of engineer battalions in the call for troops, appointing to each volunteer unit two officers of the Corps of Engineers, with increased volunteer rank. These appointments should include the major and one captain for each battalion, to be selected from the captains and lieutenants, respectively, of the Corps of Engineers. All engineer staff officers can and should be appointed from the Corps of Engineers, their places, as well as those of the officers appointed in battalions, being taken by volunteer officers, who can be readily obtained from the civil assistants now in the employ of the Engineer Department, and who are familiar with the civil duties and competent to carry on the same.

In the apportionment of the volunteer engineer battalions among the several States due regard should be had for the character of the population, whether industrial or mainly agricultural, the former being more likely to furnish men suitable for engineer troops.

The two officers of the Corps of Engineers assigned for duty with each volunteer engineer battalion should be ordered to the respective States where their battalions are to be recruited and proceed with the work of organization under the uniform regulations of the War Department governing the muster in of volunteers. Both officers and men selected for the volunteer engineer battalions should possess qualifications which will render them acceptable for the special work of engineer troops; and, in this matter, the two officers assigned to each battalion from the Corps of Engineers should be charged with discretionary power. In connection with this matter useful assistance can be rendered through the present organization of engineering districts throughout the country. In all these districts there are large numbers of men whose character and ability in the numerous civil duties are well known to engineer officers, and many of whom will no doubt respond to the call for volunteers, and will, by preference, join the engineer troops. The higher classes of these civil employees afford excellent material with which to officer the engineer battalions, while the lower classes can be utilized as non-commissioned officers and privates.

As already pointed out, there need be little fear but that abundant volunteers will be forthcoming for the organization of any needed number of

engineer battalions, and all that will be required is to exercise a wise control in their formation.

To furnish all the officers required for an adequate engineer service from the Corps of Engineers, under the pending bill, for a volunteer army, there will be required:

| | *No. of Officers.* |
|---|---|
| For 21 volunteer engineer battalions | 42 |
| For 20 divisional staff officers | 20 |
| For 10 Corps staff officers | 10 |
| For 3 army staff officers | 3 |
| Total | 75 |

While it will be a rather severe strain to furnish so many as seventy-five officers from the present strength of the Corps, the provision of the bill, permitting the appointment of volunteer officers to replace those appointed to duty with the volunteer army, will make it possible, and this should be done. The value of even a single officer of the Regular Army with a volunteer battalion is so great, and has been so well demonstrated in the Spanish-American War and the Philippine insurrection, that as large a number as possible should always be taken for this purpose.

But whatever be the law governing the creation of a field army in time of actual or threatened war, it is of the utmost importance that a proper provision be made for the needed engineer troops, coincident with the call for volunteers and militia, and that this matter should not come as an afterthought. Indeed, it would be wise if the engineer and sanitary troops were mustered into service ahead of the infantry, cavalry, and artillery and dispatched to the points of rendezvous, there to prepare for the coming of the main body of troops.

Having now discussed the possibilities of obtaining the personnel for an adequate engineer service, it is in order to consider the subject of the engineer equipment, not only of the engineer troops themselves, but also the reconnaissance instruments and engineer equipment prescribed for the infantry, cavalry, and artillery by General Orders Nos. 73 and 221, War Department, series 1907.

The engineer equipment prescribed by General Orders No. 221, 1907, for the cavalry and infantry organizations of the Regular Army has all been purchased and issue nearly completed. The purchase and issue of reconnaissance instruments called for by General Orders No. 73, 1907, has proceeded as far as funds have permitted, about half of the organizations of the Regular Army having been equipped. Speaking on this matter, the Chief of Engineers, in his annual report for 1908, says:

> At the rate permitted by past appropriations, the work of supplying the army with engineer equipment will take several years for completion.

It thus appears that the organizations of the Regular Army have not

yet been fully supplied with their engineer equipment, and that there is no reserve equipment whatever for volunteer troops.

The question of an adequate equipment is primarily one of money, and the responsibility for any failure in this respect must rest upon Congress. The only logical method for promptly supplying the field army with all its varied wants is to keep on hand an ample reserve, at least of all articles which can not be obtained without delay in the open market. This is a broad question and vitally concerns not only the Engineer Department, but the Quartermaster's and Ordnance departments as well. Since the Spanish-American War, Congress has displayed a more liberal spirit in meeting the needs of the army; but, unless larger appropriations are specially made for providing a reserve of arms and equipment, we may expect to see some of the experiences of that war repeated.

On the outbreak of war Congress may be expected to vote appropriations with prodigal liberality, and money, ample for all purposes, will become available. But there is one thing money can not buy, and that is "time." I well recall the frantic appeal for protection of a prominent citizen who called at the War Department during the early days of the war with Spain, when the phantom Spanish fleet was daily reported at various points off the Atlantic coast, and his great indignation when told there were no seacoast guns available for the defense of his home city. "But why don't you make them?" he argued, "Congress has given you plenty of money." The incident carries its own moral, and comment is unnecessary.

The element of time, always important in military operations, is doubly so for a nation whose main dependence will be on a volunteer army. Unless the volunteers can be promptly armed and equipped, much precious time will be lost in giving them at least a little training before the actual shock with the enemy. The importance of a reserve of arms and equipment for a volunteer army deeply concerns the welfare of the nation, and it seems almost incomprehensible that Congress should delay in this important matter. The present condition can not be charged to the military authorities, for the annual estimates of the bureau chiefs bear witness to the contrary.

So far as the engineer equipment of engineer troops is concerned, much thought and study have been given to the subject in recent years by the Engineer Department. An engineer field manual has been prepared and issued, and a standard company outfits adopted and published in orders from the Headquarters of the Corps. About 50 per cent of the company outfits have been issued to the regular battalions. Studies and experiments

have also been made to ascertain the best methods for packing and transporting the company outfits, and these matters are nearing a solution. Tentative lists have also been prepared of the battalion equipment and of plant tools and materials for equipping the field and reserve engineer depots to be located at the bases and on the lines of communications.

It is a matter of considerable importance that all as yet undetermined elements of the engineer equipment, including more especially the details of the field transportation and packing, be settled and published in orders as speedily as possible. The advantage of having everything relating to the engineer equipment fixed and definitely known in advance will outweigh any slight imperfections, and no unnecessary time should be lost in striving after undue refinements. The allowance of transportation for a battalion of engineers has already been definitely determined and published in orders and is sufficient for the proposed equipment.

Many articles in the engineer equipment are of such a character that they can be readily obtained in open market, without loss of time, when needed, and there is no object in encumbering storehouses and depots in times of peace with such. Every effort should, however, be made to accumulate a reserve, more or less complete, of all articles which can not be obtained in sufficient quantity in the open market without delay. This, as already pointed out, is a question of money, and is dependent upon the pleasure of Congress. Although a consummation devoutly to be hoped for, it is not likely that Congress will provide, in advance, the funds necessary for a complete reserve equipment for the volunteer army, and, hence, dependence must be had upon purchases to be made upon the outbreak of war. This will inevitably involve some delay, but this appears to be an inseparable element of our military policy.

With the known number of organizations to be supplied, and with standard lists of outfits, purchases of articles of engineer equipment can be made most readily through the engineer officers stationed in large centers of supply, on orders emanating from the Office of the Chief of Engineers, as was done to a large extent during the Spanish-American War. The familiarity of these officers with the supply markets, dealers, and manufacturers will enable them to make the best of the situation. For the ordinary working tools and equipment of an engineer battalion, purchases and deliveries can be effected as fast as the battalions can be organized. As an instance of what has and can be done in this direction, mention may be made of the fact that in 1898 orders were issued to supply the requisition of the First United States Volunteer Regiment on July 28, and on August 2 the full outfit, sufficient to fill twenty-four wagons, was on the dock ready to load on the transport. While intrenching and ordi-

nary mechanics' tools can undoubtedly be obtained in open market without delay, and in sufficient quantity to equip as many as twenty-three battalions, the same is not true of surveying and reconnaissance instruments, photographic and map-reproducing appliances, and similar equipment, which are either of special patterns for military service, or of which a sufficient stock is not kept in the market. Unless a reserve of such material can be accumulated and stored in advance, there is bound to be some delay in supplying this character of equipment.

The most serious shortage which now exists in engineer equipment, and one that would be rather difficult to supply on short notice, is that of the standard bridge equipment, one division of which, equivalent to 225 lineal feet of bridge, should ordinarily accompany each division of troops and be in charge of the ponton company of the engineer battalion.

A cursory examination of the available bridge equipage shows that three divisions of the reserve train and four of the advanced guard train can be furnished complete, with some surplus material in certain lines. It is apparent, then, that unless considerable additional bridge equipage be accumulated in reserve we will be confronted with delay and embarrassment in outfitting the ponton companies of volunteer engineer organizations on the outbreak of war.

With energetic measures and with proper inducements in the way of ample remuneration and bonuses to boat and wagon builders, it is thought that both pontons and ponton wagons, in considerable numbers, can be supplied in one month's time.

Experience in the Spanish-American War with a small number of pontons indicates that this can be done, but it is deemed unwise to defer the acquisition of bridge equipage until war has broken out or is imminent, and every effort should be made to provide an ample reserve of this equipment in time of peace and to have the same complete in all respects and ready for issue without delay on the outbreak of war.

With respect to engineer service on the lines of communication, this is a subject that has not yet received all the consideration which it merits, either in the Field Service Regulations or the Army Regulations, notwithstanding its evident importance. Whether the lines of communications be railroads or wagon roads, it is plain that their mere maintenance, due to wear and tear, not to mention possible interruptions resulting from hostile enterprises, will call for much work and attention. Engineer depots must be maintained at the base and along the lines of communications, to hold reserves of tools, materials, and equipment, both to replace losses at the front and to render available, on short notice, such heavier and bulkier plant and materials as hoisting engines, pile drivers, portable

electric plants, bridge timbers, field railways, etc., for which there will be occasional urgent use. Vital points of the lines of communication near the front will also require defensive preparation, such as redoubts, blockhouses, etc. For all this work it is plain that there should be a contingent of engineer troops for duty on the lines of communication.

In what has preceded it has been assumed that twenty divisions of troops would be organized into three armies, each having its own line or lines of communication, with an independent service, and provision has been made for one reserve engineer battalion for each army to look after the necessary engineer work. The reserve engineer battalion will be under the immediate orders of the commander of the base and lines of communications, with general duties about as follows:

1. Care and maintenance of the engineer field depots.

2. Maintenance of the lines of communications between the base and advanced field depot, including repairs to all parts of the line, as well as the construction of additional lines or sidings.

3. Construction of defensive works required to protect vital points of the line. While the duties of the divisional battalions will be mainly tactical, those of the reserve battalions will be largely administrative. Except for very short lines, it will not be practicable for a single engineer battalion to attend to all the engineer duties on any one line of communications with its own personnel, and the employment of civilian labor on a large scale may become necessary. For this purpose the commander of the battalion should be amply provided with funds, with authority to expend the same for any purpose connected with the maintenance and guarding of the lines of communications. With such an arrangement it is believed that the service of the lines of communications can be readily maintained, so far as the engineer work is concerned. In view of the probable nature of their services it would be well if the reserve engineer battalions were drawn from the ranks of railroad employees; and, if this object be kept in view at the time of the muster in of the engineer battalions, it can easily be accomplished.

In what has preceded this paper has endeavored to point out the possibilities of securing an adequate engineer service under existing laws and conditions. It must be admitted that, at present, no perfectly satisfactory engineer service can be expected; but, then, this may be said, with equal truth, of a satisfactory artillery or cavalry service, or, in fact, of any other service. If the truth be confessed, we are still sadly deficient in the matter of a proper preparation for war; but ground has been gained since 1898, and the great point is, that the Army itself is alive to the situation, is making

strenuous efforts to improve matters, and that the nation, through Congress, is turning a more willing ear to military needs.

So far as regards the engineer service, it can be safely stated that the Corps of Engineers has endeavored to keep up with the other arms of the service in securing recognition of its needs in order to be prepared for war, and has labored earnestly to this end with the means available. In its three regular battalions the Army has as efficient an engineer contingent as any army in the world, and these battalions can unquestionably be relied upon to perform any engineer service within reason.

In considering the immediate needs of the future as regards the engineer service of our army, they may be briefly summarized as follows:

1. The accumulation of a reserve of engineer equipment, more especially of bridge equipage.
2. Prompt and definite decision as to details of the equipment of engineer troops, including packing and transportation.
3. An increase in the regular establishment of at least three battalions.

While the need for an increase in the regular engineer establishment is probably no more urgent than in some other branches of the Army, it is at least equally important. The value of a well-trained and well-equipped engineer battalion in facilitating the operations of a division can scarcely be overrated. Good communications, admitting of easy and rapid movements of troops and supplies, will frequently obviate the necessity for reenforcements, and in this one particular alone the engineers are prepared to render a good account of themselves. Let us therefore have as many trained battalions as the limitations of our military system will permit.

# The Relation of the Federal Government to the Owners of Undeveloped Water Powers on Technically Navigable Streams*

*BY*

J. E. SIRRINE
*Mill Architect and Engineer*
*Greenville, S. C.*

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*Mr. President, and Gentlemen of the Congress:*

Enough has been said during this session to convince every member of this body of the pressing need of the conservation of our resources, but little has been said of the equally pressing need of utilization of those resources which may be termed non-exhaustible. Given even a fairly decent forestry policy the water-power resources of this country may be used without dimunition forever, and by a comprehensive system of development may be increased over their natural or normal power by at least twofold. The effect of their utilization upon the use of coal is so patent that only the slightest reference need be made to it.

Notwithstanding the fact that the development of the textile industry in the Southern States during the past fifteen years was the most rapid industrial advance in the history of this country, there is enough water power in the southern Appalachian region to drive ten times the number of spindles running in the South to-day.

Many of the sites for future power plants are remote from markets, and the commercial necessities of the present day will not warrant their development, but their ultimate utilization is sure, and it remains for us to consider how best to hasten this development, for no one will dispute the manifest advantage of the speedy use of this inexhaustible force of nature.

Broadly, the streams may be divided into two classes, navigable and non-navigable, and the former class in the one upon which the functions

*An article prepared at the suggestion of Governor Ansel, of South Carolina, for the Congress of Governors, held at the White House, May 13–15, 1908. The author is a prominent and successful hydraulic engineer, with a large experience in water-power development.

of the State and National governments are to be exercised. With the latter class, the non-navigable streams, it is purely a question of commercial expediency with the riparian owners as to how the development shall be made and when it is warranted.

The navigable streams may be divided into two classes. (1) Those whose prime importance lies in their availability for use as waterways and are actually navigable or can be made so at an expenditure commensurate with the benefits to be derived.

(2) Those that are technically navigable, because they are the boundary lines between States and whereon no actual navigation is practiced nor can be practiced without an improvement of such magnitude and expense as would be entirely out of proportion with the benefits to be derived therefrom.

With the first class of these two it is undoubtedly the right and duty of the General Government to make such improvements as are warranted, and if in the course of such improvement there is created a salable water-power privilege, they should undoubtedly require the user of it to pay a suitable toll for such use.

The same is true where the United States is the owner of the riparian rights, and in no case should the individual or corporation expect to secure the free use of a water power owned or made possible by the Government.

There are, however, many streams of the second class on which navigation can not be practiced and where the improvement for navigation would not be warranted by the commerce which might reasonably be expected.

In such cases where the riparian rights are in private hands it would seem a wise policy on the part of the Government to encourage rather than restrict the development of the properties. There need be no conflict between the legitimate use of such streams for power purposes and their present or subsequent use for purposes of navigation. As a matter of fact it is clearly to the advantage of all power companies to have cheap transportation near their power plants, so that they can induce the owners of manufacturing plants to locate near them and thus save the cost of transmission lines, as well as the loss of power due to long-distance transmission.

The average cost of water-power developments in the southern Appalachian district, certainly as favorable a district as can be found in the country, is not less than $150 per horsepower, and in some cases it runs much higher. Thus cost includes all charges for construction of plants as well as distribution, and upon this basis the earnings must be made.

Money for such industrial developments is rarely available at less than

7 per cent, and taxes must be counted at 1½ per cent. Running expenses and repairs will average 2 per cent and depreciation as much more, making a total charge of 12½ per cent, or $18.75 per horsepower, which must be paid before the riparian owner gets anything.

It should be remembered that these are fair average figures, and if we are ever to realize the full value of our water powers, the policy of the Federal Government should be to provide for such rights in respect to future navigation as will insure to the public the use of the stream when it becomes navigable, either through the construction of a sufficient number of dams entirely by private parties or by the assistance of the Government; but it does not seem fair or right for the General Government to penalize the use of such properties.

In many of the streams in the Southern States that are navigable in their lower reaches one or more of their tributaries form the boundary line between two States and are technically, therefore, navigable streams under the jurisdiction of the United States.

Frequently these are torrential mountain streams or are so precipitous in their slopes as to render absolutely impossible even the rudest forms of navigation, and the entire absence of any form of town or settlement on the banks make it reasonably sure that for many years no navigation can be had or is desired. This is especially true in the States of North Carolina, South Carolina, and Georgia, where there are no coal or ore bodies at the heads of the streams and where the lumber is practically exhausted, leaving no bulky or heavy freight to be handled.

A good example of such a stream is the Savannah River, which forms the boundary line between South Carolina and Georgia, either in the main stem of the river or one of its tributaries, from the Atlantic Ocean to the North Carolina line. The lower part of this stream from the mouth to Augusta, Ga., lies in the coastal plain and is now used by steam vessels for a portion of the year and by pole boats all the year. Above Augusta and up to the mouth of the Broad River of Georgia it is navigable for pole boats, and while the amount of commerce is small, it does exist, and it would be only fair for the Government to require that provision be made to take care of this navigation by parties seeking the right to dam the river.

Above the mouth of the Broad River the river is practically a succession of shoals, and the cross section is of such varying depth as to render it dangerous for even small rowboats. No navigation has ever existed on this portion of the stream nor is any likely to exist without the expenditure of many millions of dollars for the construction of locks and dams.

The water-power possibilities of the Savannah River are great, and

with a comprehensive system of development the profile of the stream would be changed to a succession of pools, where an easy ascent or descent from one to the other could be made with locks that could be put in as the needs of navigation required or as the improvement of the river made possible. However, at the present price of coal electric power in large units and with steady loads can not be sold at a larger price than $20 per horsepower per annum for sixty hours per week, from which must be deducted a fixed charge of $18.75 for interest, taxes, depreciation, and operation, leaving a profit of only $1.25 per horsepower to the riparian owner, unless he be so fortunate as to have a peculiarly favorable site or be near enough a large center of power users so that he can dispose of a portion of his power in small units at large prices.

This close margin makes it extremely difficult to secure financial backing for what is a more or less hazardous venture, and accounts for the large number of water-power propositions now vainly seeking capital for their construction.

Of the total cost of a lock and dam on a stream of this character the dam is generally 75 per cent and the lock 25 per cent, this being based on a lock of usable dimensions of about 25 by 150 feet with 25-foot lift.

Therefore, if the riparian owner is required to construct a lock in addition to building the dam, he is practically barred from making the development until the increasing price of coal has enhanced the selling value of his power, and, in addition to this, the improvement of the river will be still further delayed.

In the long run the customer who buys the power, and this practically means the general public, suffers by reason of the delay, and every obstacle placed in the way of the water-power utilization only hastens the inevitable exhaustion of the coal supply, which might be postponed many years by a full development of all the water powers of the country.

There is enough water power in the United States to do the work of 500,000,000 tons of coal annually, while our present consumption of coal is only 470,000,000 tons annually. Of course, much of this power can not be developed for many years, and some of it may not be commercially feasible until the coal is practically exhausted, but much of it can be brought into commercial use now if a liberal policy on the part of the State and National governments be adopted rather than one that is apparently farsighted, though actually shortsighted. No surer way of getting a speedy development of our natural resources of both water power and water resources can be found than that of making the burden as light as is consistent with public policy on those corporations or individuals who are trying to develop water powers, and while willing to assist in

making the rivers navigable, are at the same time limited by the commercial features of the proposition, since it goes without saying that no owner will make an improvement that he does not think will pay. There are undoubtedly some properties so favorably situated that the owners could afford, and might, rather than be stopped from making their improvements, be willing to submit to the requirement, that they should not only assist, but bear the whole expense of creating a navigable condition where none formerly existed; but this would be in the nature of taxing a farmer, by requiring him to bear the whole expense of road building, through his property, because his land was more fertile than his neighbor's.

There should be no objection to a reasonable limitation in the length of time the owner should enjoy his rights in matters of this kind, leaving, as the President has wisely suggested, future generations to decide what policy shall be adopted toward this class of corporations.

The writer would suggest the following as his idea of the proper restrictions to be placed on such enterprises:

First. Streams actually navigable and now used, or capable of being used, for navigation.

A suitable lock to be constructed by the petitioner for the charter, at his whole expense, with an annual toll to the State or National governments, according to the nature of the case, suitable provision being made for lockage as will allow the public no dimunition of their previous right and ability to use the stream for the purpose of navigation.

Second. Streams that are not actually being navigated and where the riparian rights are owned by the State or National governments.

A suitable provision for the construction of locks when necessary and an annual toll charged for the use of the water rights. The amount of toll to be governed by the conditions.

Third. Streams that are only technically navigable and where the cost of improvement would be so great as to render it inadvisable for the Government to make such improvement, and where the riparian rights are held by private parties.

On streams of this character, which forms much the larger part of the available water powers, it would seem fair that provision should be made in the grant for a right, on the part of the Government, to build locks, whenever it may be justified, with such restrictions as will enable the locks to be operated properly, if built. The Government should also see that dams are so located that the subsequent and final improvements of the stream will not be interfered with.

By this plan the largest part of the cost of improvement will be borne

by private parties and at the same time no potential or actual right of the public is infringed on in the slightest degree.

On the contrary, the ultimate improvement of many streams will be hastened and the final cost to the public of such improvements to navigation will be only one-fourth of what it would be were the Government to undertake the improvement unaided.

Before closing this paper the writer desires to say a few words on the subject of improved waterways.

Everyone agrees on the advantages of good water transportation, but the question of how far to go with any proposed improvement is strictly a commercial one, to be decided by the cost of the work and the ultimate benefit to be derived therefrom.

This involves a close study by trained engineers, and as no report can fully set forth all the conditions, nor any person not thoroughly versed in a subject be capable of properly and fully deciding weighty matters connected with that subject, it would seem wise that any commission to recommend legislation on the improvement of our waterways, or to supervise such improvements, should have at least a majority of its membership composed of engineers, and these engineers should be drawn largely from the one organized body of men who have given the subject the most study and who are entirely free from any influence of outside, individual, or corporate interests.

This body is the Corps of Engineers, United States Army.

# Durability of Creosoted Lumber in Sea Water*

The Sandy Point Dike was built to produce scour and increase the depth across Fort Hale Bar. The first appropriation for this dike was that of August 2, 1882, for $30,000, and a plan for the dike was approved by the Board of Engineers October 2, of that year. Apparently the dike itself was begun during 1883 and continued thereafter until 1889. Originally the plan called for two rows of creosoted piling, 8 feet apart, filled in with stone, and it was for this purpose that the piles referred to in the attached letter were furnished, but in 1886 the method of construction was changed, riprap being afterwards used instead of the piling, so that all of the piles must have been driven not later than 1886. According to the Annual Report, from which most of the above data was obtained (Annual Report of the Chief of Engineers for 1890, page 619, *et seq.*), the outer portion of the shore-arm, 846 feet long and 254 feet at the north end of the channel-arm, were built of the creosoted piling, under plan shown in Fig. 1. The piles composing the shore-arm vary from 7 inches to about 9 inches in diameter at the exposed end, while those on the channel-arm seem to run somewhat larger (from about 8 to 10 inches in diameter) and were apparently better piles in the beginning. All of the piles are driven quite close together, but not as a rule in absolute contact. Generally speaking, the condition of the piles is good, particularly those in the channel-arm, most of these being in remarkably good condition, so that not over 5 per cent in this portion of the dike are seriously impaired, and many are apparently in as good condition as when they were first driven. In the shore-arm the conditions are not as good, although the greater number of the piles are apparently perfectly sound and good, but there are a number that are in very bad condition, and some which are practically entirely destroyed. By actual count, starting at the inshore end of the shore-arm and working out, out of 532 piles, taken as they came, 400 were in good or very fair condition, and 132, about 25 per cent, were in poor or, in many cases, very bad condition. It was noticed that as a rule the piles which had deteriorated occurred in bunches, so that there might be three, four, or even eight or ten, one after another, all of which were in bad condition,

*Abstract of Report by G. E. Verrill, Assistant Engineer to Major Taylor, Corps of Engineers, March 15, 1909.

and then there might be fifty or sixty which were all in good condition. No reason could be discovered for this, except that apparently the piles which had deteriorated in most cases show the creosoting strongly, but in a few cases no evidences could be detected of it, and probably some of the worst of the piles were never creosoted at all. As a rule the deterioration

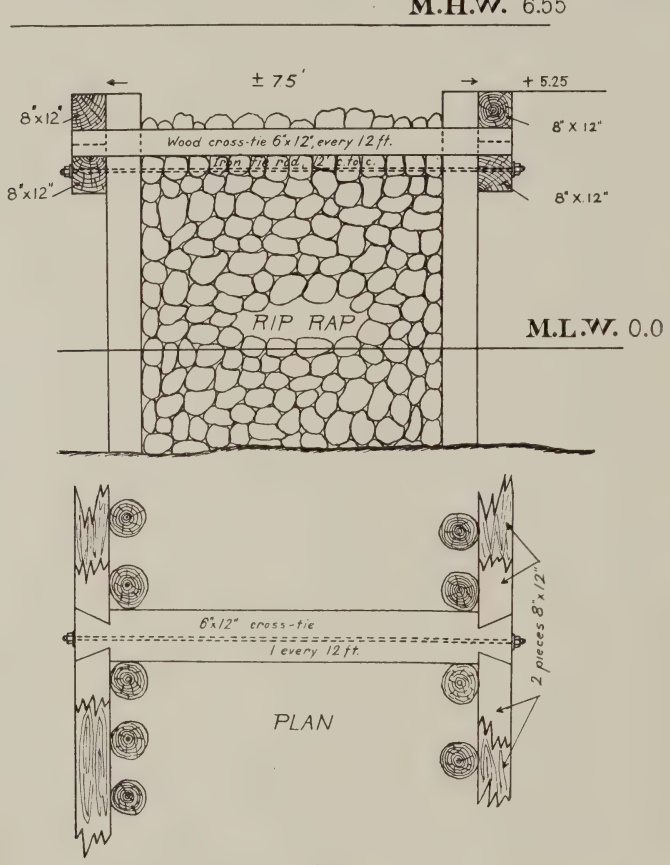


Fig. 1.

is apparently entirely due to rotting, and this rotting apparently begins at the top of the pile in the middle and works down, frequently leaving an outer shell which averages about an inch in thickness, which is still sound, although, of course, this shell is as a rule split from the top down. Apparently if the top of the pile had been thoroughly protected no deterioration would have taken place.

Very few instances of teredo attack were observed, and these were where the pile had evidently begun to deteriorate from rot before teredo began. As stated above, the piles on the channel-arm were in much

better condition than those on the shore arm, very few, indeed, being in bad condition and none of them entirely useless. The waling pieces along the sides of the dike have for the most part entirely disappeared, but this is apparently due to the rusting off of the iron bolts which held them in place, and not to any fault of the timber. Wherever portions of the waling pieces remain, they were in very fair condition, except from wear due apparently to the action of the ice, waves, etc.; for the top portions were badly slivered, but the wood itself was remarkably free from rot and teredo attack. The wooden cross-ties were not in as good condition as the waling pieces, but most of them were still present, and as a rule not in very bad condition, considering the length of time they have been in place. That portion of the dike which is actually under water at low tide could not be examined, but, so far as could be judged, the lower portion of the piles is in better condition than the upper portion.

Generally speaking, the piles had stood remarkably well, for the conditions are severe, the piles being alternately covered at every high tide and exposed at every low tide.

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NEW YORK, *March 3, 1909.*

Maj. HARRY TAYLOR,
*Engineer, U. S. A., New London, Conn.*

DEAR SIR: During the year 1883 we furnished a lot of creosoted piles for building a United States Government dike at New Haven, Conn.

Those piles were treated by the Full Cell Process of creosoting with dead oil of coal tar.

We have recently been looking up some of our oldest creosoting work to ascertain how the process has preserved the timber, and we find the above are among the first creosoted piles used in that part of the country; therefore we are very desirous of learning how the piles have lasted.

If agreeable to you, we wish you would kindly have an examination made of those piles at your earliest convenience, and then advise us what condition they are found to be in.

As they were put in place over twenty-five years ago, it should be of interest to all concerned to learn how well the creosoting has preserved the piles.

Thanking you in advance for the favor of your kind attention, we are,

Yours, very truly,

EPPINGER & RUSSELL CO.

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UNITED STATES ENGINEER OFFICE,
NEW LONDON, CONN., *March 17, 1909.*

The CHIEF OF ENGINEERS, U. S. Army,
*Washington, D. C.*

GENERAL: I have the honor to enclose herewith copy of certain correspondence, thinking the same may be of interest. The samples referred to in Mr. Verrill's letter are not forwarded. It may be remarked, however, that a very strong odor of creosote comes from the samples and that the paper wrapping in which they have been done up for three or four days is already discolored by the creosote which has exuded from the wood.

Very respectfully, your obedient servant,

(Signed) HARRY TAYLOR,
*Major, Corps of Engineers.*

# Regulation of Rivers in the Interests of Navigation*

*BY*

Henry L. Abbot
*Professor of Hydraulic Engineering*
*Late Colonel, Corps of Engineers*

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The character of a stream depends upon the area of its watershed, its rainfall, its slope, and the geological nature of its bed. Regulation may be required in the interests of navigation, or for protection against overflows, or for the generation of water power, or for irrigation. The first specially concerns large streams, and forms my subject to-night.

## LOCAL IMPROVEMENTS

High stages usually afford as ample facilities for navigation as can reasonably be expected; it is the low stages which call for artificial aid. At such times sand bars extending diagonally downstream in prolongation of points at bends often block the passage, and the channels cut through them in sudden rises vary so much in location as to confuse pilots; formerly at New Orleans when the river carried a large local commerce conferences were frequent between the pilots of ascending and descending boats to learn the latest changes of channel. Among the early improvements were attempts to increase the natural depth on such bars by means of spur jetties or training walls, composed of piles and hurdles, designed to locally contract the flow and cause lateral deposits; but the great improvements in dredges of late has tended to cause a resort to that method in preference.

When a river brings down large quantities of drift logs, to become snags or so-called sawyers, serious obstruction to navigation results; and the Government has expended large sums for their removal by boats equipped with special machinery for this purpose.

Where the banks admit of erosion by river currents, extensive caving

* Lecture delivered before engineer students in the post-graduate courses, George Washington University, March 17, 1909.

especially in bends occurs, tending to obstruct the channel; to prevent this, bank revetment by brush mattresses, supplemented by hydraulic grading to form suitable slopes, has often been practiced where the expense is warranted. Various methods for constructing these mattresses have been employed. The following has proved very successful near and below St. Louis: A location for beginning the mattress was selected where the water was shallow near the concave shore just above the caving bend to be protected. Anchoring piles were driven, here and below, parallel to the shore and about at the low-water line; all snags and obstructions were removed from the area to be protected, and whatever local bank grading was necessary was done. The mattress, about 125 feet wide and continuous in length, was designed to sustain a layer of stone extending over it from its outer edge to the low-water line, there joining another layer protecting the graded slope above. One revetment of this kind near Fosters Island was 6,000 feet long, and has served its purpose for twenty-five years, where the annual caving had been about 200 feet.

The outfit for wattling the mattress was the following: Three barges, each about 125 feet long, were employed; one to serve at first as an anchorage for the upper end of the mattress, and later to protect its construction by occupying oblique positions over it to deflect drift logs, often brought down by the current moving at a velocity of 5 or 6 feet per second, and acting like veritable battering rams. The two other barges carried the materials and the men to construct the mattress. One of them was equipped with a solid frame carrying 20 "fingers," 6 feet apart, gently sloping up from the water's edge, and designed to support the unfinished end of the mattress when making. The latter was formed of about 20 continuous stringers, often of cable or wire rope, but in this locality, of willow sticks about 20 feet long, from 6 to 8 inches at butts and 4 inches at the small ends. They were securely lashed together with wire at joints. The wattling was of small, straight willows about 3 inches at butts, the leaves being retained.

To construct the mattress, the upstream barge was moored at right angles to the shore with one end abutting against the bank; the mooring ropes, extended well upstream, were made fast to large trees; the "finger" barge occupied a parallel position at a short distance downstream, held to the first by strong cables and by one end of the 20 stringers, the other ends being held at water level by ropes on the upstream boat. The third barge, loaded with willow, was lashed alongside the second, her end abutting against the bank. It should be noted that the strong cur-

rent threw great stresses on all the barge cables, so that it was necessary to pass them under the barges and make them fast to the timber heads on the side whence the stress came, otherwise the barges would be torn asunder.

All being now ready, the wattling of the mattress began. Men were stationed at each of the 20 "fingers," holding alternately up and down the ends of two stringers resting on each, so that men on the barge below could slip wattling pieces down the fingers into place, in a manner to form a regular basket work. As the work progressed, the cables were slackened and the two barges dropped gradually downstream, securing the mattress to the piles as they passed. When about 600 feet had been thus completed, the loading with stone to sink the floating mass commenced. This began at the upstream end and continued about 300 feet. When all was ready, the ropes holding the upstream end were simultaneously cast off, the upper half sank into position, and the loading of stone on this 300 feet both on mattress and bank was completed, the two downstream barges meantime continuing the construction.

One other local river problem is worthy of mention. When a stream makes large bends, the bights often approach each other, and natural cut-offs may occur, soon taking the form of crescent lakes by the silting up of the terminals. As the distance to be navigated is materially shortened by such cut-offs, they have sometimes been made artificially, where this could be done at reasonable expense; but experience has proved that increased water heights and increased caving of the banks below are certain to result, and now on the Mississippi they are carefully prevented by bank revetment. Bends are recognized as a useful provision of nature to adjust the slope to the material forming the bed and banks. Such are some of the local measures employed by engineers to improve navigable rivers.

## RESERVOIRS

Another plan often proposed by those not conversant with the technical difficulties involved contemplates the holding in reserve of flood volumes in reservoirs constructed upon the upper tributaries, to be released in the low stages and thus to artificially supply the volume needful for navigation.

It should be remarked at the outset that the fundamental principle involved is sound, and often regulates in an important manner the natural flow of streams. Such, for example, as where natural lakes collect large volumes of rainfall and deliver it gradually to outflowing streams; as where large river beds by successively filling and discharging serve the same

object; as where the soil itself absorbs much rainfall and releases it through underground flow to springs and rivulets, and ultimately to the rivers; indeed, snow drifts, and under certain conditions forested tracts, may become natural reservoirs, tending to regulate outflow in a way to improve navigation. But when the attempt is made to apply this general principle to artificial regulation, special local conditions are essential to success; such, for example, as sites suitable for dam construction at localities having large drainage areas above, where the lakes will not submerge lands valuable for agriculture perhaps already occupied. Furthermore, it is often assumed that lakes thus created will also supply water power for mills, and thus will be doubly useful. It is forgotten that to serve this latter purpose a regulation of the outflow quite different from that demanded for the improvement of navigation may be essential. Perhaps the best way to appreciate the limitations of the reservoir plan is to study the results actually reached at the district where it has been applied on the largest scale in the United States; namely, on the upper Mississippi above Lake Pepin, Minn. It is well to judge a tree by its fruit.

## UPPER MISSISSIPPI RESERVOIRS

The Upper Mississippi heads in a region remarkable for the number of its natural lakes; and, when the works were authorized by Congress in 1882, large Indian reservations presented conditions unusually favorable in so far as resident population was concerned. Navigation both above and below St. Paul was seriously impeded by insufficient depth in the season of low water, and its improvement by artificially enlarging the numerous existing lakes and regulating their outflow was undertaken by the Government.

The purpose of these reservoirs was to collect the surplus water from flood years, and from the relatively rather large precipitation of winter, spring and early summer, to be released in a manner to benefit navigation in the low stages as far down as Lake Pepin, some 40 miles below St. Paul. The general level throughout the entire district, some 1,000 or 1,500 feet above tide, differs so little locally that large areas can be flooded by low dams. Five reservoir lakes have been completed, discharging into the Upper Mississippi—Winnibigoshish, Leech, Pokegama, Sandy and Pine River—and several more were projected. To avoid legal difficulties with land proprietors, it was needful to secure land titles for flowage areas to a height 4 feet above the highest proposed lake level. The dams, originally of timber, have been replaced by steel concrete. The total cost

of construction and operation to July, 1905, was about one and a half million dollars. The dimensions of the system are the following:

*Reservoirs on the Upper Mississippi.*

| Reservoir. | Completed | Above St. Paul. | Watershed. | Area in square miles. | | Fluctuation in feet. | Capacity in million cubic feet. |
|---|---|---|---|---|---|---|---|
| | | | | High water | Low water. | | |
| | *Year.* | *Miles.* | *Square miles.* | | | | |
| Winnibigoshish | 1883–4 | 413 | 1,442 | 161 | 117 | 14.0 | 43,992 |
| Leech Lake | 1884 | 447 | 1,163 | 234 | 173 | 5.7 | 33,094 |
| Pokegama Falls | 1884 | 351 | 660 | 45 | 24 | 7.5 | 5,260 |
| Sandy Lake | 1895 | 271 | 421 | 16.5 | 8 | 9.4 | 3,158 |
| Pine River | 1886 | 200 | 562 | 24 | 18 | 16.1 | 7,733 |

The hydrology of the three upper reservoirs, whose combined volumes enter the Mississippi at Pokegama Falls, appears from the following figures, representing the average of the records for twenty years:

Annual precipitation, 26.5 inches, or 202,000 million cubic feet.

Annual outflow, 5.5 inches, or 42,200 million cubic feet, or 1,339 cubic feet per second, ranging between 2,330 and 390 cubic feet per second.

Average percentage, precipitation and outflow, 20.9 per cent.

The mean annual evaporation from the water surfaces of the reservoirs is believed to equal the precipitation thereon, so that no contribution to the mean annual outflow of the district can be collected from rain or snow falling upon these water surfaces. The available watersheds of the five reservoirs constitute 11.8 per cent of the whole area above St. Paul, and 21.5 per cent of that above Minneapolis; the corresponding figures for the three upper basins being 9 per cent and 16.6 per cent.

The rate of transmission of the wave caused by opening the gates of a reservoir is at first retarded by the volume absorbed in filling the intermediate channels, but when this has been accomplished the rise below becomes more rapid. Released at Pokegama, where the flow of the three upper reservoirs is collected, the influence begins to be felt at St. Paul, 351 miles below, in about ten days.

Such are the statistics; it remains to consider the practical results of this reservoir system. The laws of Congress prescribed that the funds shall be solely used for the improvement of navigation, and no part for the benefit of private property; and devolved upon the Secretary of War the prescription of rules and regulations for the use of the reservoirs. The following are these regulations, in substance, for the government of the engineer in charge.

The surplus over the ordinary low-water supply to the reservoirs, and

so much of said low-water volume as may not be immediately needed for any purpose below any dam, shall be stored until the limit of capacity or safety of the reservoirs is reached, or until water is needed for navigation upon the streams below the dams.

During the season of navigation on the Upper Mississippi River, the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a uniform and sufficient stage of water in the navigable reaches of the Upper Mississippi and in those of any tributary thereto that may be navigable, and on which a reservoir is located. The discharge may, however, at any time be increased or diminished in order to admit of inspection or repairing the dikes and their appurtenances.

This matter of regulating the flow, which many inexperienced advocates of grand systems of reservoirs for the improvement of navigation have overlooked, has proved to be far from a sinecure to the engineer in charge; and in 1905, in view of vigorous complaints of damages, it became necessary to send a board to investigate and report upon the subject. Riparian interests both above and below the dams had suffered in various ways from the increase in flooded area caused by raising the water level, and were clamoring for an abandonment of the system, as were also some milling interests both above and below. After careful investigation the board rejected the complaints of parties above the reservoir dams; the works were not for their benefit, and the reservation or purchase of flowage rights had covered such claims as appeared to be otherwise legitimate. Below the dam sites the question was more complex. At the town of Grand Rapids, 2.5 miles below the Pokegama dam, was located an important paper mill, for which the natural lakes gave greater regularity of flow than when the reservoirs are regulated in the interests of navigation. The milling interests and considerable local interests dependent thereon suffer from this regulation; although so far as possible the difficulty had always been met by releasing during winter months all surplus flow over what was needful to conserve in the reservoirs in order to have a sufficient volume in store when navigation opened. Milling interests considerably farther downstream suffer much less if any interference, as contributions from lower tributaries meet their needs in part during the winter period of storage, when navigation is suspended by ice. In this lower district, however, complaints of a different character were raised. The artificial reserves released during the summer and autumn so considerably increased the normal low-water flow that sudden freshets in the

lower tributaries due to local rainfall caused inundation of low cultivated districts, and thus aggravated natural conditions.

In fine, to what extent such complaints may be well founded can only be determined by a judicial study of local conditions both before and after the construction of a system of reservoirs, and also of the rules under which the latter are to be regulated. Experience in the practical operation of the Upper Mississippi system has unquestionably demonstrated that the needs of navigation and of water-power generation are more or less conflicting, and that the idea of satisfying both by a single system of reservoirs is visionary.

The actual benefits resulting to navigation from the Upper Mississippi system are measured by an average increased low-water depth at St. Paul of about 14 inches when the release of water is uniform, and of about 22 inches when the release is specially regulated to effect the maximum benefit. These figures are based on the records of twenty years, during which, as already stated, the total outlay, including construction and operation, was about a million and a half dollars. Local popular sentiment, especially in the thickly populated district below Minneapolis, appears to favor the system as on the whole beneficial, notwithstanding the opposition of interested parties. One great benefit permitted by the vast capacity of the storage basins is that the surplus volumes in years of heavy rains may be accumulated to assist navigation in years of drought; but, on the other hand, the impossibility of foreseeing the character of the season in advance may bring about occasionally an actual augmentation of some of the local flood volumes. This actually occurred to a limited extent in 1905 at Aitken, situated 134 miles below Pokegama dam and 55 miles below Sandy Lake dam.

As a general proposition it seems legitimate to conclude that reservoirs form only a contingent element in plans for the improvement of navigation; that the interests of navigation and of water-power generation may seriously conflict as to regulation of the outflow, and hence mutual benefits can hardly be claimed; and that, in a word, whether or not resort should be had to them in any special case can only be determined by local conditions. Simply as flood regulators they may even tend to aggravate natural conditions on the main river, by promoting a coincidence in the contributions of the great tributaries, which is the primary cause of destructive floods. Reservoirs on the tributaries of the Ohio, for example, might naturally tend by retarding and prolonging the flow to augment the volume of floods from the Missouri and Arkansas, usually later in date, and thus cause increased inundations below Cairo. Their utility even for water-power generation has recently become a matter for discussion; the

use of one of them on the Merrimac River, by the water-power companies at Lowell and Lawrence, has been abandoned as unsatisfactory after many years of operation. It remains, however, to see what will be the influence of recent developments in the way of transmitting energy to long distances by electricity, which can hardly fail to largely increase the demand for all kinds of water power. For providing reserves for lockage on canals, and for irrigation when needed for agricultural purposes, the use of reservoirs has become general, and their great utility is unquestioned.

## CANALIZATION

Another method of improving navigable rivers is that known as canalization, by which at low stages navigation is assisted by movable dams and locks. This system is much in use in Europe, and is now largely applied to the Ohio below Pittsburg, a distance of over 1,000 miles. Here works of improvement have been in progress since 1824, looking first by local expedients to securing a minimum navigable depth at low water of 3 feet; in 1875 this projected depth was increased by 45 movable dams to 6 feet; and in 1905 by 54 movable dams to 9 feet, both being revised estimates. The period of low water covers the months of August, September, and October, when the volume at Pittsburg is about 1,600, the maximum flood volume being about 440,000, cubic feet per second. The slope at low water is about a foot per mile in the upper 85 miles, and about 4 inches per mile in the lower 70 miles; the total fall is 424 feet, of which 26 feet are at the falls near Louisville, around which a canal, since largely improved, was opened in 1830 for use at low stages, the falls being drowned out at high stages. Such conditions are well suited to a system of improvement combining locks with movable dams.

The first dam on the Ohio was completed in 1885 by Major Merrill at Davis Island, 5 miles below Pittsburg. Six of them are now in operation on the upper 30 miles, and appropriations for eight more have been made by Congress. It is generally recognized that by no other system can the desired 9-foot depth be secured. At high stages the movable wickets are lowered, and vessels ascend and descend through the navigable pass thus opened; at low stages the wickets are raised, forming in the river bed a succession of navigable pools, which are entered successively by the vessels with the aid of locks. Any deposits of sand are removed from time to time by dredging.

The present annual commerce is estimated at 10,000,000 tons, and is chiefly restricted to downstream traffic, owing to the difficulty of ascending the river against the current. A stern-wheel boat with from 12 to 20

barges will make the trip from Pittsburg to Louisville in five or six days; thence, a larger towboat will conduct from 30 to 60 barges to New Orleans in from eleven to thirteen days, each barge carrying a freight of 1,000 tons. About 90 per cent of the freight is coal, and with the 6-foot navigable depth, floods and running ice excepted, the cost per ton mile is about half a mill or, say, 15 per cent of ordinary railroad rates. Increased channel depth will specially favor upstream traffic, and will thus materially benefit downstream as well, because the necessary return of the barges has always been a drag upon the latter.

## FOREST CONSERVATION

It only remains to consider one other method proposed of late to benefit river navigation, that of conserving the forest growth upon the mountains, where the tributaries take their rise. This has been advocated as a universal corrective, both reducing the floods and increasing the flow at low stages. The question of forest conservation is quite independent of such claims, and is not strengthened by such vague assertions. There is no doubt that our forests have been squandered most recklessly in past years, and that hereafter they should be carefully conserved and where practicable restored. The reasons for this conclusion are unanswerable and require no support from doubtful claims. For example, at the close of the Civil War our experience in military bridges had been very great, and advantage was taken of it to prepare detailed specifications for future bridge equipage of the army. The balks, as the main beams connecting the boats are called, were to be of white pine having great strength and light weight, which latter is of prime importance, since the army must carry the equipage as well as be carried by it. At the outbreak of the war with Spain it was found that this special quality of timber had disappeared from the market, owing to the wasteful destruction of the trees, and it had become needful to make use of inferior and heavier balks. The yellow pine of our southern forests is rapidly becoming scarce, and the redwood forests bordering our Pacific slopes, under ill-considered methods of lumbering, are disappearing as did the buffaloes that ranged our western plains half a century ago. Our forests must be conserved, and no doubtful claims are needed to reinforce the argument.

Under certain conditions it is doubtless true that forests do exert a useful regulating influence on stream flow. The Chagres River, flowing where frost is unknown, is an example. The flow during the three low-water months has been proved by careful measurement to proceed almost wholly from the forest soil which has become gradually saturated with water during the nine rainy months; and there is little doubt if the dense

forest now covering the watershed were removed that the floods would be increased and the low-water volume be diminished. But when these tropical conditions are modified by altitude, frost, and especially by snow, as in the Yellowstone National Park, observations show that the exact reverse may be true. Of the threefold claim that forests increase rainfall, that they reduce floods and increase low-water flow, and that they prevent soil erosion, the first is unsupported by facts, and the second and third are purely local questions, depending on local climate and topography. The so-called "forest reservoirs" can have no intelligent control of outflow, so essential to artificial reservoir utility. A statistical study of recorded stream flow for a limited period in this country, and for several hundred years in Europe, demonstrates that changes in forested area produce no well-marked effect upon floods or low stages, notwithstanding current assertions to the contrary. The true explanation of such annual variations of flow as do appear may well be found in variation in precipitation, which is well known to be subject to periodical progressive changes. In fine, the conclusion seems inevitable that the conservation of forests offers little or no aid to the utilization of our rivers for navigation needs; its importance rests on other grounds.

# The Accident to the Canadian Canal Lock Sault Ste. Marie, Ont.*

*BY*

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The Canadian canal on the north side of the St. Marys River at Sault Ste. Marie, Ontario, has a length of 1⅛ miles and is 150 feet wide and 22 feet deep, with a lock at its lower end 900 feet long, 60 feet wide, and having a 22-foot depth of water on its miter sills. The lock has masonry side walls, wooden gates, and is filled and emptied through wooden culverts which extend under its floor and miter sills. There are five sets of gates, the upper and lower guard gates which are used when the lock is to be emptied for examination or repair, the upper and lower service gates which are ordinarily used for making lockages, and an intermediate set of gates which can be employed in place of the lower service gates whenever necessary.

At the time of the accident, about 12.50 p. m., June 9, the lower service gates were closed and the lock filled with water. The Canadian Pacific steamer Assiniboia had entered the lock from above and been tied up, the Pittsburg Steamship Company's freighter, the Crescent City, was entering the lock and her stern was over the upper miter sill; there was also approaching the lock from below the Gilchrist freighter, Perry G. Walker. There is a conspicuous sign below the lock directing upbound vessels where to stop. As the Walker was passing this sign there was a misunderstanding in signals between the captain and engineer, and the boat struck the south pier a glancing blow and crashed into the southern gate, while moving at the rate of 6 miles an hour, as estimated by the employees of the Canadian lock. The blow drove in the southern gate, and the northern gate when the mitering was destroyed swung downstream apparently little injured, but snapping the iron straps which hold the heel post in place and breaking some of the upper stones of the hollow quoin. The water pressure tilted up the bottom of the southern gate, which then forced the Walker down the river and swung free of its miter sill. The

* The photographs herewith are permitted to be published in the Memoirs only, through the courtesy of Young, Lord & Rhoades, Ltd., Sault Ste. Marie, Mich.

Fig. 1. Lower Gates.

lower third of the gate is badly twisted. The location of the gates after the accident is clearly shown in Fig. 1.

The Assiniboia broke her moorings and started down the river, striking the Walker a glancing blow, which straightened her out, so that the Crescent City was able to pass her without hitting.

According to the Canadian authorities, the Crescent City rubbed the upper miter sill and then passed out of the lock without doing further damage. The captain of the boat, however, states that the first effect of the accident was to cause the bow of the boat to hit the bottom of the lock and that the stern became submerged and struck the lower miter sill as she passed out. After the Crescent City passed the Walker she collided with the Assiniboia, which had attempted to come to anchor, and both boats were considerably damaged. The Walker then proceeded to crash into both piers as she drifted down the river.

The cables holding the upper gates parted after the accident to the lower gates; the gates failed to miter when they met and were wrecked. They were found in the canal between 200 and 300 yards below the lock. The other gates remained uninjured in their recesses. (Figs. 2 and 3.)

The Canadian authorities had constructed a movable dam to be placed across the canal above the locks should ever the gates of the lock be carried away, and its manipulation is of particular interest, as there is under contract a similar structure for closing the enlarged canal to the Poe Lock, and this is the first opportunity that has occurred to test this form of dam. The movable dam consists of a swing bridge, one arm of which spans the canal when swung in place and abuts against two heavy concrete piers. To the lower chord of the bridge are attached girders, which when not in use occupy a horizontal position under the bridge, but are pivoted so that they can be lowered and rest against a sill on the bottom of the canal. In these girders slide wickets which obstruct the flow of the water. The bridge is worked by hand, but was so difficult to manipulate that it was necessary to obtain the assistance of a team of horses. It was started at 2.50 p. m. and was in place at 3.30 p. m. The girders were then lowered, but several of them did not come into place on account of some obstruction against the lower sill, but the force of the current was sufficient to gradually remove these obstructions except at one girder, which became badly distorted after remaining down overnight and had to be raised. At 3 a. m. all the girders had been lowered and two-thirds of the wickets. Difficulty was experienced in forcing down the wickets, the rollers having rusted so that several of the wickets had to be driven into position by jacks. Stop plank was substituted for the wicket of the twisted girder,

Fig. 2. Upper Gates.

and considerable difficulty was experienced in getting the lower ones in place. (Fig. 4.)

A short time after the accident and before the movable dam was in place the surface velocity through the lock was found to be 15 feet per second and about 7 feet in the canal. On the 12th a measurement of the surface current above the movable dam with the stop plank across the gap within 8 feet of the bottom was found to be 1¼ feet per second.

On the morning of the 13th the gap had been filled, and at 1 p. m. the closing of the intermediate gates of the lock was begun. There was still considerable current through the lock, and the closing of the gates was a delicate operation. Two tugs were moored to the side of the lock to reduce the current by the action of their wheels. The emptying valves of the lock were opened and additional cables attached to heavy timbers on the lower faces of the gates. These cables were very gradually played out, and when the lower ends of the miter posts came together the upper portions of the gates, I should judge, were about 4 feet apart, and there was about 1 foot head against the gates. They, however, mitered successfully at 2.15 p. m.

The upper guard gates were closed the 13th without incident, and during the night the lower guard gates were closed, after clearing away considerable débris that had collected along the sill.

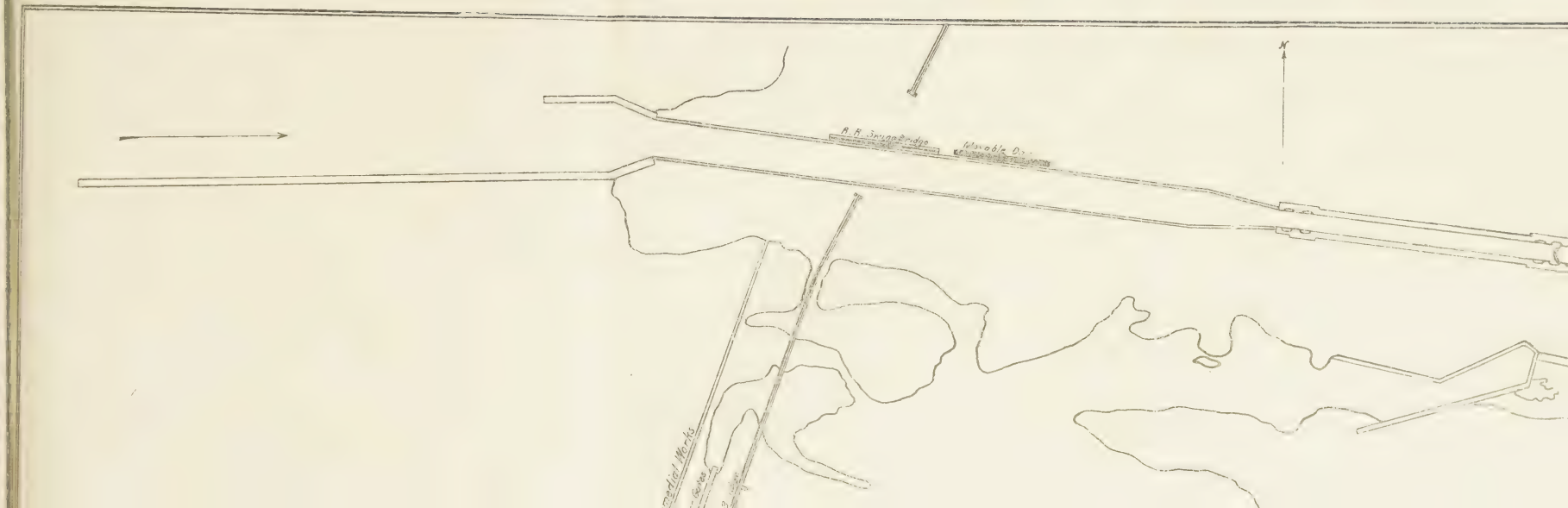
Aside from the wrecking of the gates, the damage apparent to the lock seems to be confined to the following: The gratings over upper culvert well were nearly all washed out and bent more or less. The sheaves on miter wall of upper operating gates were badly broken and parts washed away. Below the miter wall the lock floor was damaged—nine timbers over one culvert were broken, and the double flooring torn up, more or less, for about 50 feet. The sill of intermediate gate was slightly damaged, also the sill to the lower service gates. The above-mentioned damages were repaired, and new gates, which, fortunately, were on hand, were substituted for the upper service gates. At 6 p. m., June 21, the movable dam had been removed, and the lock was ready for service, the intermediate gates being used as lower service gates.

As the possibility of such an accident was foreseen when the Weitzel Lock was constructed, and has been discussed as each of the other locks has been proposed, a rediscussion of the subject is not considered necessary at this time, but there are several practical points which were developed by the accident which are believed to be worthy of mention. The accident to the upper gates indicates that there was either a certain play to the cables or engines, which permitted the gates to move out of their recesses, or that they were not entirely closed when the lower gates collapsed, and

Fig. 3. Upper Gates.

a strong automatic clutch in the gate recess similar to a car coupler, which will require action by employees to open, instead of to close, as is now the case, is considered advisable for every gate. When duplicate sets of gates are relied on to prevent such an accident, as is the case on the new lock authorized on the American side of the river, the culverts should fill the space between the two upper sets of gates faster than the body of the lock, and the space between the two lower sets of gates should be filled less rapidly to insure keeping all the gates mitered. There is considerable surging of the water while filling the Poe Lock, and the intermediate gates are not always closely mitered. As these spaces are emptied this mitering is of less consequence, as there will then be two other sets of gates closed. Heretofore at the Poe Lock if vessels pass the stopping place they have been successfully checked by lines from the boat to snubbing posts, though occasionally those lines have parted. If a vessel with 10,000 tons of freight in her should approach the Poe Lock at the rate the Walker was reported to be moving, neither the chains proposed for the Panama Canal nor cables could be expected to stop her. The possibility of considerable exaggeration in such reports, however, is recognized.

The movable dam performed the functions for which it was designed and was therefore a success. Many of the defects which developed in maneuvering it were foreseen in the plans for the dam now under contract for the American canal. The proposed dam is to be operated by electrical power instead of by hand, and reliance is placed on a pull by cables to bring the wickets into position in addition to gravity. There will also be less danger of the rollers getting out of order. While the girders are to be more strongly braced than in the Canadian design, they are still considered too weak to resist the torsional strain that results when an obstruction gets under one end of the girder. It is proposed to strengthen the cross bracing, so as to prevent the girder from being strained beyond its elastic limit, replacing rods with angle irons differently spaced. A quick method of closing the spaces between the girders, and a means of diminishing the discharge between the wickets and girders, is being devised, it being considered inadvisable to attempt to close the steel gates of the Poe Lock against such a current as was running at the time the intermediate gates of the Canadian lock were closed.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R. R. Swing Bridge
Movable Dam

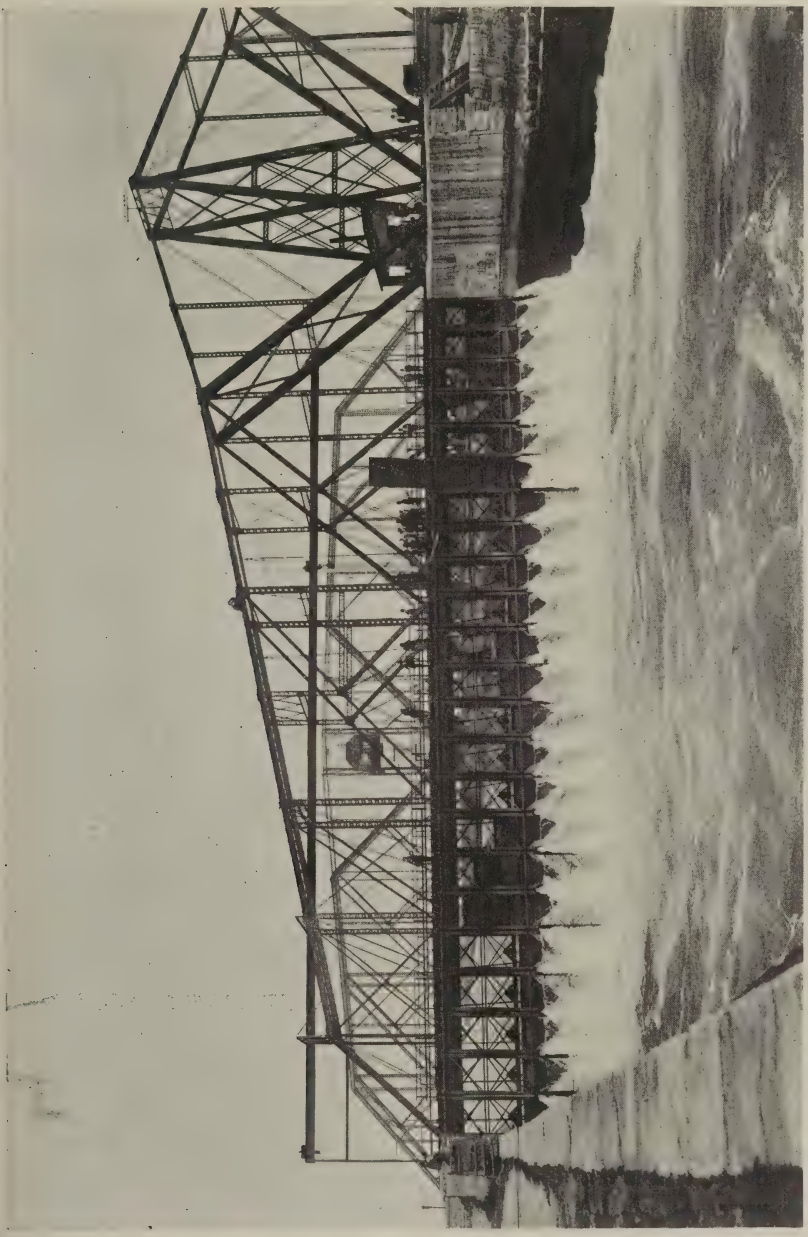

Fig. 4. Movable Dam.

# THE ENGINEER SOLDIER: HIS TRAINING

*BY*

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The first duty a young engineer officer usually encounters after his graduation from West Point is with the engineer troops. The first man with whom he has strictly business relations is the engineer soldier.

Early experiences are strongly impressed on a young man's mind, and doubtless now there is none of the older officers of the Corps who does not remember some Sergeant Burke or Corporal O'Hara of the old Battalion of Engineers, with a thought of what he could do, whether the fight were with mortal man, or fire, or water, or, in times of peace, with the fire-water that lurks beyond the guardhouse gate. Perhaps their training was good; I am not prepared to say.

When I first joined the old battalion a few of those old non-commissioned officers were still present. Some who had made lashings on the bridge at Fredericksburg were just passing out, and I had great faith in their training and was willing to submit myself to their teaching. Those men were trained by officers who had gone, but who had left the imprint of their characters. Our duty is with the soldiers of the future.

The proper training of an engineer soldier is a problem abounding in difficulty with which many an officer has wrestled, only to find that the more his efforts were prolonged the more mystified he became. In my short experience with the troops I have considered the subject and have come to such a conclusion. When I sum up the duties and estimate the capacity of the ordinary man, I am sure how a bantam hen would feel were she detailed to hatch out a nest of ostrich eggs. But even the hen would have sufficient intelligence to take them one at a time; or, if she had not, the nature of the case would compel such a mode of procedure, even though some of the eggs would spoil through neglect.

In military training the field of work must necessarily be narrow and well defined to insure successful results. In times of peace we lose sight of the simplicity that must characterize all of the operations of war. Only the simplest of these operations can be carried out in times of excitement

and hurry. Simplicity must be the watchword in plans of operation, in orders, in action, and in equipment. Directness can be secured only when simplicity pervades the whole machine. It is in the interest of simplicity of training that I write this paper.

Doubtless many will disagree with the few ideas that I may present, but I am confident that, in so far as my own capabilities are concerned, the duties commonly assigned to the troops which we call engineers are too extensive to be performed within the organization of a company or of a battalion. This is the conclusion that some experience and considerable thought have forced upon me.

Since the field of operation for engineers in campaign is unlimited, the proper handling of the subject of training men to perform the function of engineer soldiers would be to specialize along certain lines, assigning to certain organizations certain fixed duties not beyond their capabilities to perform with perfect ease and efficiency, letting the less important or more complicated alone. At present, so far as my knowledge goes, this effort is not being made, though, doubtless, the directing authorities have long ago seen the necessities of the situation. The first difficulty lies in the very small number of engineer troops and of officers at the command of the higher authorities. To cover a large field requires a large organization, and this not being in existence, it becomes necessary to omit from the list of work to be done such items as can not possibly be covered by the force available.

The second difficulty to the proper training of our engineer troops is the unsettled condition of our service which requires the troops to perform work of a special nature in various parts of our territory to the neglect of any fixed course of instruction. Our engineer troops have been made to do valuable service in our foreign possessions, and it has been such as to require all of their time. The service may have been what the troops would naturally do in campaign, and it may not. But the result has been such as to discourage and prohibit what should properly be the peace training of a military organization. This is another feature which could not be avoided, but which in time may pass out of existence. The requirements of service in the Philippines and Cuba have interfered greatly with the proper training of all branches of the army, but with none so much as with the engineers. It may take years to build a military road, and if the engineer troops are assigned to that work road building of that special character is all they will learn. It may take years to make a map of an extensive territory, and if the troops are assigned to such work they will know map making, but nothing else.

An examination of the duties commonly assigned to engineer troops

will at once make evident the difficulty one meets in an effort to reduce to reasonable simplicity the training our troops should receive.

Firstly and foremostly, the organization must be one of soldiers—fighting men; masters of the rifle. They must have discipline and must be able to act as infantry. This feature can not be eliminated. Our country is not in the business of educating a conglomerate of tradesmen; they can be had at any time for hire. It is soldiers that are wanted, and the engineer battalions must be able to take their place on the firing line along with the best. Few will deny this. But this is a big item in the time required for training. Infantry can not be made in a moment. Will not this item almost exclude all others from our list? It would if the organizations were not always leavened with soldiers of several terms of enlistment.

The next most important accomplishment is a thorough knowledge of field fortification and all that goes with it. This is carrying out the idea of the soldier.

We place next in importance a thorough knowledge of explosives. War is far more a game of destruction than of construction.

Bridge building is commonly assigned to the engineers, and of all the kinds of military bridges the ponton bridge is the only one of importance. Other kinds of bridge building belong to times of peace, or, at best, in the rear of an army, where civilians may work out of the way and at their leisure with derricks, traveling cranes and what-not to aid them. The military bridge builder has no time for ponderous machinery.

Road building is another bugbear; it does not belong to the engineer troops of our army; it does not belong to the man at the front; it is the proper duty of the civil engineer and the patient day laborer in the rear. Only the improvised road belongs to our troops; the corduroy, the plank, or any kind of a makeshift that may get the artillery over, and then let us move ahead. Abolish the idea of a good road. Talk to the military engineer of a good road and he ought to be insulted. Good roads, like good maps, require the patient labor of peace times. They don't belong to the pioneer—the master of the ax and the rifle—the best man in the field that the world has ever known and now knows not at all.

Now we come to that detestable, debauched word, reconnaissance—French in its origin and Parisian in its peace-time elegance. What have we made it mean? and what a fantastic burden have we given it! It has come to mean the making of maps, the handling of delicate instruments of precision, surveying, anything from the taking of astronomical observations for latitude and longitude to the reading of an aneroid barometer. Alas! the engineer soldier must know reconnaissance! He must be a

map maker, a draftsman, a topographer — things to which men devote their lives to gain proficiency.

While we are on this subject of map making, let us deliver our strongest sentiments, subject to contradiction. I am convinced that the idea of extensive map making with an army in campaign is an impossibility. Generals who expect any body, engineers, or cavalry, or topographical experts, to turn in an accurate map of the country in advance of the army in campaign are doomed to disappointment. Mapping is a peace-time vocation of experts. Any system of mapping a country in advance will require the army to sit down and wait and the enemy to go to sleep. I believe those who are leading the authorities to believe that such work can be done are building a house of cards to fall about our ears in war time. Maps are fine to have, but you must have them in your pocket when you march. Your surveyors, your topographers, must have made them long before you take the field. Furthermore, your surveyors must be highly skilled in the art and devote their entire time to the work.

Now, there are many other duties requiring highly technical skill, that may be assigned to engineer troops, but I feel sure that they should be performed by civilians whose lives have been devoted to such work, not by the enlisted men of the engineer battalions. Engineer officers would of course be able to secure the necessary skill and supervise its application. These duties involve questions of all permanent construction — steel, masonry, and timber; electric light and power, steam power, railroad construction, water-supply engineering, sanitary engineering, and anything in the field of engineering. None of these things belongs to the engineer soldier.

It is to be noted that the operations of the maneuver camps have greatly unsettled the military mind as to the powers and limitations of the engineer troops of the line.

Turning now to our little force of engineer troops, let us give our idea of what they should be.

In two words, they should be pioneers or pontoniers. Nothing very scientific about a pioneer; a very simple man. Nothing very complicated about a pontonier; another very simple man. But each, in his way, is invaluable when properly trained. Both should be excellent infantry soldiers, whose strongest argument is a straight rifle shot.

The pioneer gets his name from the fact that his place is in front. From the character of our fathers we know him as the master of the ax and the rifle. But from our knowledge of present warfare we must make him the master of the pick and the shovel as well, and of high explosives, too. There is your pioneer and his equipment; only to the latter we must add a few

other things of modern adaptation. His kit is that of the infantryman complete. But his ax, his pick, and his shovel are man size, and must have their proper transportation.

What sort of a man should he be, and how would I train him?

He should be a robust boy from the farm. None of your broken-down, out-of-a-job tradesmen for my pioneer soldier. I want the simplest, soberest, upstanding young hulk of a man that the insides of our country can put forth, with hands like hams and a waist like the trunk of a white oak. No city boy need apply.

First, I would make him master of his rifle. Then he should be made, by actual practice, master of the ax and the crosscut saw (2-man). The pick and shovel are homely instruments, but he would know them as his best friends, or, if not best friends, his worst enemies, for he would have to bow to them almost every day. He would be a past master at trench-work. He could fell a tree overhanded and underhanded, right-handed or left-handed. He could tie all the knots and make all the lashings, not only on a clothesline in his barracks, but on a full-sized rope in the field when heavy timbers are tottering. The lines would part before his "dead men" or his "hold fasts" would pull out. He could pull a boat with the best on the river, and swim with a line in his teeth.

His more intelligent brothers would know all there is to know about the practical side of field fortification; know what rifle bullets, shrapnel, and shell can do to material; know what trenchwork could be done in a given time; know how to handle a working party; know how to put infantry on a line in the dark and give them their tools and put them to work; know how to conceal trenchwork, how to blend it with the landscape; know how to construct all the obstacles and where to put them, also the best way to tear them out.

In the field of explosives the non-commissioned officers should know all of the practical side of the explosives of trade — how to store them, transport them, and use them. Every first-class private would be able to prepare a charge and fire it, and know what to expect it to do. They would have their lectures, but only on practical experience would reliance be placed.

I would teach selected men enough of surveying, sketching, and plotting to enable them to do the work of that nature which is essential to pioneer operations — laying out a camp, sketching a defensive position, making profiles and cross sections of work that had to be done by their organization, but not with the idea of general and indefinite mapping.

There would be one man who could take photographs with a simple

kodak for the purpose of preserving records of his company's work — not a professional photographer for division headquarters.

Of course, the command would be made familiar with the various improvised bridges — spar and trestle — with all classes of ferry rigs, and with the use of tackle in handling heavy timbers, guns, wagons, etc.; with improvised road making, corduroy, plank, and earth.

This, in brief, would be the work of a pioneer company.

The pontonier would be much the same class of man, but his business would be bridge building as a specialty, and his equipment would be the bridge equipage of the United States Army. He would be required to manufacture and to maintain this equipage, with the exception of the rolling stock, perhaps. He would be truly an expert in his line.

I regard the bridge equipage as the most important factor in the equipment of the military engineer. Small expeditions in special circumstances may never feel the need of it, especially when pitted against such enemies as Aguinaldo's army. A large force confronted by an active, intelligent enemy is more or less helpless without a good and well-manned bridge equipage. No other military bridge building can take its place. No large force can be mobile without it; a river with its bridges down must be crossed, and crossed expeditiously if the enemy is a military one. Grant's campaign from the Rapidan to the south of Richmond was possible only with a river-crossing power at his call, which has never been excelled.

Our bridge equipage has made no progress in the last forty-five years, mainly because there have been no pontoniers to study it, work with it, and devote their whole time to it. No criticism of anyone or any set of our public officials is meant by this statement. No doubt some work has been done at odd times by those who could give the subject but a passing thought when crowded along by other and pressing duties. The secret of improving the ponton material and the military bridge service is the assignment of a certain number of our engineer companies to pontonier duty permanently, and the turning over to the directing officer of those companies the funds obtained for carrying on the work. The officers of those companies would be the "board" on the subject, and with the undivided assistance of the command would soon bring the subject up to date, and keep it there. Washington Barracks is the ideal station for these companies, with the Potomac at hand and the historic streams of Virginia within marching distance to the south.

All of the companies engaged in ponton work and its auxiliary work of military bridge building should be at one station in order that their efforts might be directed in coordination.

At the post mentioned one battalion might be stationed, two companies

of which would be pontoniers and two pioneers, and so give the student officers of the School full opportunity to see both classes of work.

As to the training of the pontonier, little more need be said than that he must be a good waterman in all that it means, must know the material and its adaptations thoroughly, must be able to build it, to improvise it, and must also know all that there is to be known about military bridges in general. In the construction of ponton equipage it might be necessary to employ a certain amount of skilled civilian labor, but this necessity would be small at first and would decrease as the work became more familiar.

An engineer officer in command of the troops of his Corps in the field has a trying position to fill under any circumstances; and it is in his interest that I approach the subject of the proper training of the engineer soldier. If the instrument with which a man works is ill adapted to the task, then woe to the man. The blame justly falls on him, not on the instrument; it is for the man to choose and to sharpen the tools with which he is to operate. But we may claim a higher reason for wishing to avoid failure and lay our efforts to a desire to promote the general welfare of our military forces. If we fail in our sphere of action, our pride may be hurt, and our reputations may be ruined. Small, indeed, would be such a result to our country. But our individual failures may be not only disastrous to ourselves; they may entail disaster on great operations in which all of our forces are involved. This is the consideration which should most powerfully promote in us the desire for efficiency. Fortunately, the personal and, to a certain extent, the selfish factor acts in conjunction with the higher and patriotic one. For downright practical results I attach more weight to the personal and selfish desire to be proficient in one's profession in order to have no fear of personal failure. Let the patriots sing when the victory is won, and let the selfish proficient be happy in the song.

# Pressure of Concrete on Forms

*BY*

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During the season of 1908 experiments were made at Lock No. 1, on the Mississippi River between St. Paul and Minneapolis, with a view of determining the pressure of concrete on forms at various temperatures and rates of filling.

The lock walls are made up of monolithic blocks 25.75 feet high. Each block was built in a single working day, so that there are no horizontal joints. The ingredients of the concrete were mixed about in the proportions of 1:3:5½, and the mixture was very wet, so that the forms had to be water-tight, and the workmen sank in about 18 inches. The weight was 152 pounds per cubic foot. There was therefore considerable pressure on the forms. As it was not known beforehand just what this pressure would be, the forms were designed by good guesswork or judgment, and answered very well; but measurements were made for future use.

The necessity for definite knowledge was brought forcibly home by the fact that, when cold weather set in, some timbers broke in one of the forms which had been successfully used all summer; and, again, after alternate monoliths had been completed and we were filling in the intervals, one of these great blocks, on a fine, bracing, autumn day, began to tip over. The experiments were therefore far from superfluous.

The measuring apparatus is shown in the accompanying photographs. A cylinder 9.23 inches in diameter, fitted with a piston made of two one-fourth-inch metal plates with half inch of leather between, was fastened into the side of the form about 18 inches from the bottom. Although the piston was well greased with a heavy oil for the first experiments, grit found its way to the leather, which accounts for the large initial pressure required to move the piston on August 27 and September 14 and 18. After the latter date, the end of the piston was covered with several inches of soap.

This made it tight and practically frictionless, as shown by the later observations. The weight arm or beam of the gauge is about 5 feet long and is graduated in feet and tenths. The constant of reduction was not known to the observer who took the readings. His records gave merely the weight leverage, from which the pressure per square foot was figured in the office.

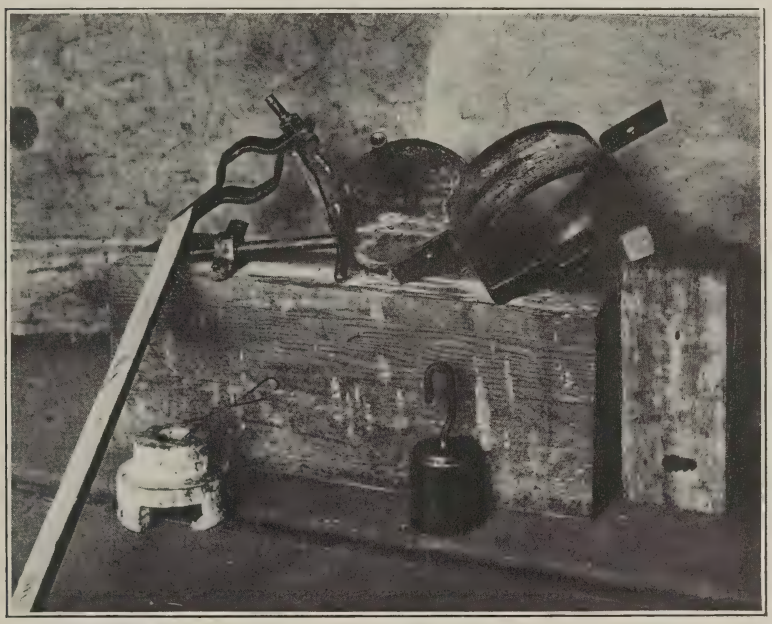
Concrete not being a freely moving liquid even while exerting liquid pressure, it was impossible to obtain absolutely accurate pressure measurements. To meet this difficulty as far as possible, an adjustable pivot was put in between the arm and the piston. By means of this the piston could be moved independently of the weight arm. At each pressure determination, the weight leverage, having been previously increased, was decreased until the concrete pushed the piston out and raised the weight arm. After recording the weights and their lever arm, the weight leverage was increased until it was considerably greater than the concrete pressure leverage, and the arm was lowered by turning back the pivot.

When the form had been filled another half foot, the next determination was made in the same way. Before the readings it was usually necessary to move the piston in and out a quarter inch or so until the observer felt it to be "alive" (as was said). The recorded pressures are those at which the concrete followed up, *i. e.*, actually moved the piston out against the weight leverage. They are very much smaller than those represented by the weight leverage required to bring the arm down. It was to avoid this pressing in against the concrete that the adjustable pivot was inserted. As the setting of the concrete proceeded and the arch action of the particles increased a point was reached at which the concrete would suddenly refuse to "follow up," and while there undoubtedly was still considerable pressure on the form the gauge would no longer record it, and observations ceased abruptly, as shown on all the curves. This point, however, was never before the maximum pressure had occurred.

The results of the experiments are shown on the accompanying diagrams. These diagrams are of two kinds, which may be called records and deductions, respectively. Each record sheet contains two curves or lines. One shows the relation between time and the height of the surface of the liquid concrete. The abscissa is time (as indicated at top); the ordinate is height above center of piston. The other line shows the relation between pressure and the height of the surface of liquid concrete. The abscissa (as shown at bot-

tom) is pressure in pounds per square foot. The ordinate (as before) is height above center of piston, or head of concrete. Neither of these lines is derived from the other. Both are plotted from direct observation. Each record sheet also shows a plan and elevation of the monolith on which the experiment was made.

One of the record sheets (No. 8) also shows, in dotted lines, what the pressure would have been at various rates of filling. These



curves were computed and are of course deductions. They are shown in this sheet for purposes of comparison.

The method of deducing the final curves was as follows: The pressure on the piston at first is that due to pressure of a liquid weighing 152 pounds per cubic foot. After a time, the pressure on the piston becomes less than the liquid pressure, because the concrete begins to act as a solid, and is then equal to the liquid pressure minus a certain resistance due to setting and arch action, which (for lack of a better name) has been called strength. The time at which this strength begins to show varies with temperature, pressure, condition of rest or agitation, and, perhaps, other things. From the data available a formula for time of initial strength has been deduced, which is $T = C + 150/R$, in which T is time in minutes

after filling has begun, when concrete begins to show strength, R is rate of filling in vertical feet per hour, and C is a constant depending on temperature of concrete. Values of C for the usual temperatures are as follows:

| *Temperature.* | *C.* |
|---|---|
| 80 | 20 |
| 70 | 25 |
| 60 | 35 |
| 55 | 42 |
| 50 | 50 |
| 40 | 70 |

The temperature considered here, as elsewhere in this discussion, is the temperature of the mixture in the form.

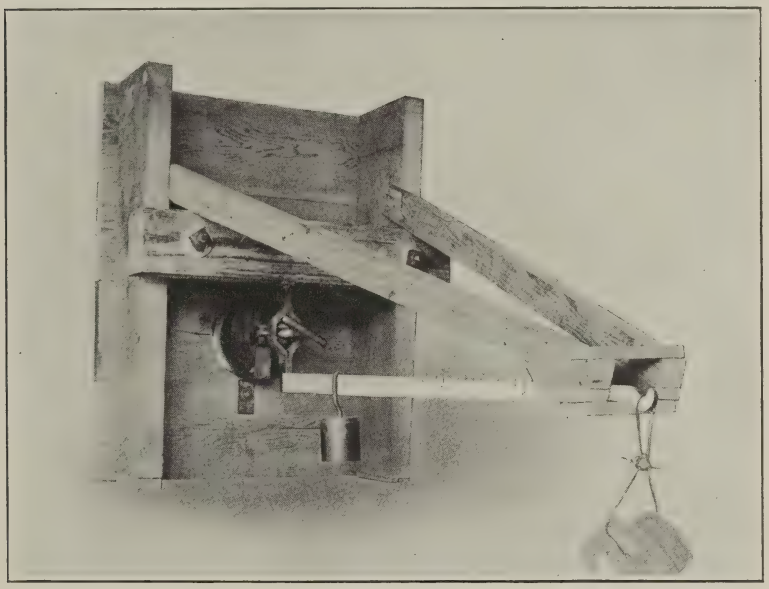
It appears from the formula that the concrete shows strength more quickly as the rate of filling is greater. This is because a given layer is more quickly protected from the effects of agitation on the surface when the rate of filling is rapid than when it is slow. In the latter case a given layer may be for an hour or so kept in constant agitation by the trampling of the men, dumping of material, etc. The effect of pressure, which doubtless exists, is so disguised by the effect of agitation that it can not be detected.

Sheet No. 2 shows the relation between R, strength (as above defined), and liquid pressure for a fixed temperature of 60°. The time of initial solidification, and increase of strength, are deduced from the observations for various values of R and are shown to the left by curves whose abscissas are pressure in pounds per square foot, and whose ordinates are time in minutes. The liquid pressures at these various rates are shown by the right lines to the right. The time of the maximum pressure is the ordinate of the point (marked by a short normal) on the curve S where the tangent is parallel to the line of liquid pressure for the same value of R. Its value is the horizontal distance between the curves of S and P at this time.

From diagrams like No. 2, one for each temperature, the curves on Sheet No. 1 are plotted, the values of R being entered as ordinates, the maximum pressures as abscissas. There is a separate curve for each temperature.

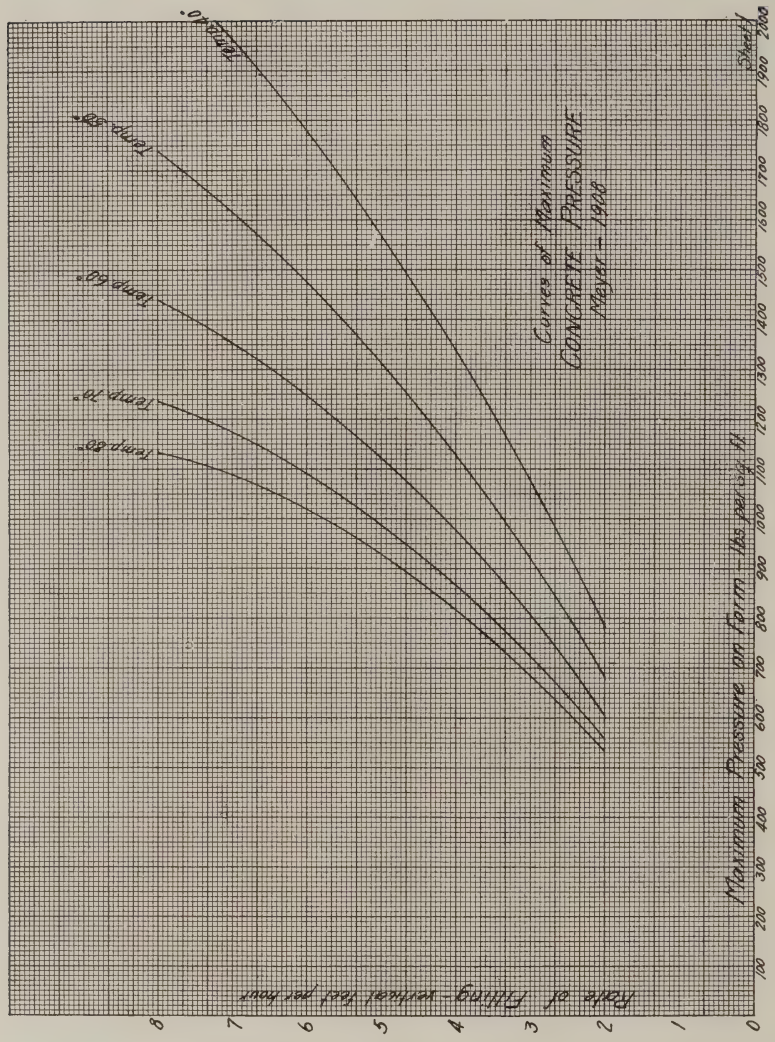
These curves may be used for two purposes; either to determine the strength to be given to forms, or to determine the safe rate of filling for a given form. In the first case, it is necessary to determine, from records of the locality, the lowest temperature to be

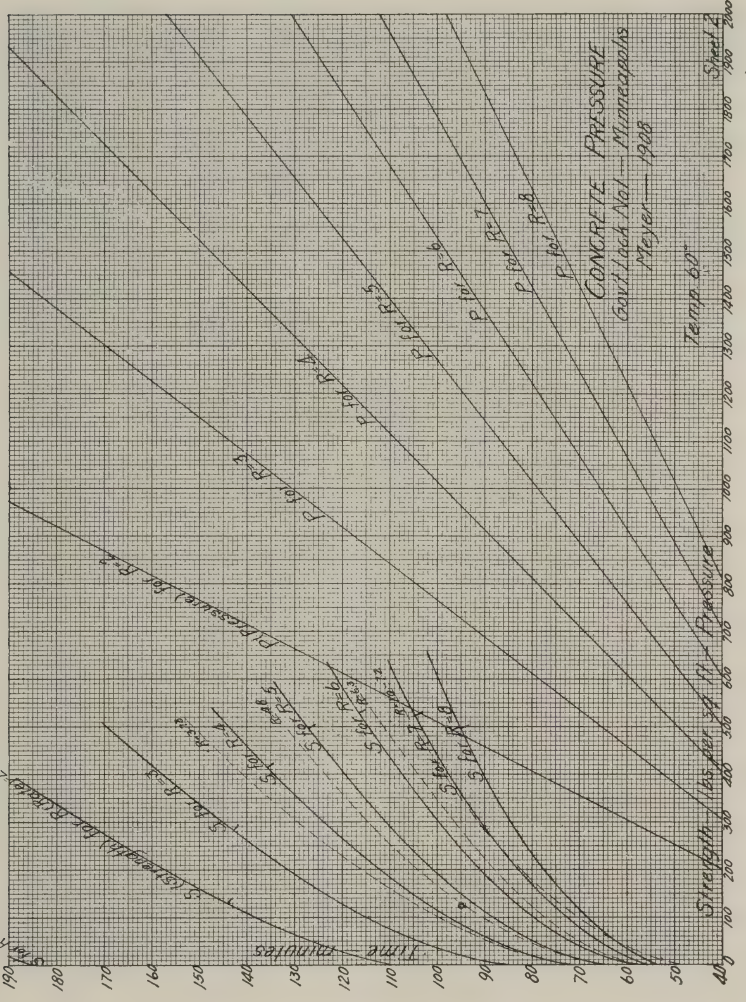
expected, and, from the dimensions of the blocks to be built, the highest desired rate of filling. Suppose that the lowest temperature is 40°, and the desired rate of filling 7 feet per hour. Follow the horizontal line 7 until it intersects the curve for 40°, and drop a vertical to the axis of X. This shows that the forms must be designed for a pressure of about 1,900 pounds per square foot. In the second case, suppose that the form is designed for a pressure of 1,000 pounds per square foot, and that on a given day the tem-



perature is 60°. Follow the vertical line 1,000 until it intersects the curve for 60°, thence a horizontal line to the axis of Y. This shows that the safe rate of filling is something over 4 feet per hour.

I am far from claiming absolute accuracy for the results obtained, but I think they are sufficiently exact for the purpose, which is not to establish a theory of molecular physics, but only to find a practical rule for determining strength of forms or rate of filling. During the coming season I expect to use a larger piston (2 square feet in area if possible) and to make a greater number of measurements. Advice will be cheerfully received.


Curves of Maximum
CONCRETE PRESSURE
Report - 1908
Temp 0°
Temp 32°
Temp 60°
Temp 70°
Temp 80°
Rate of Filling - vertical feet per hour
Maximum Pressure in pounds per sq. ft.


CONCRETE PRESSURE
Gen'l Hosp. Nat — Minneapolis
Meyer — 1908
Temp 60°
Sheet 2
Strength lbs per sq. ft. Pressure
Time Minutes
P for R=8
P for R=7
P for R=6
P for R=5
P for R=4
P for R=3
Pressure for R=2
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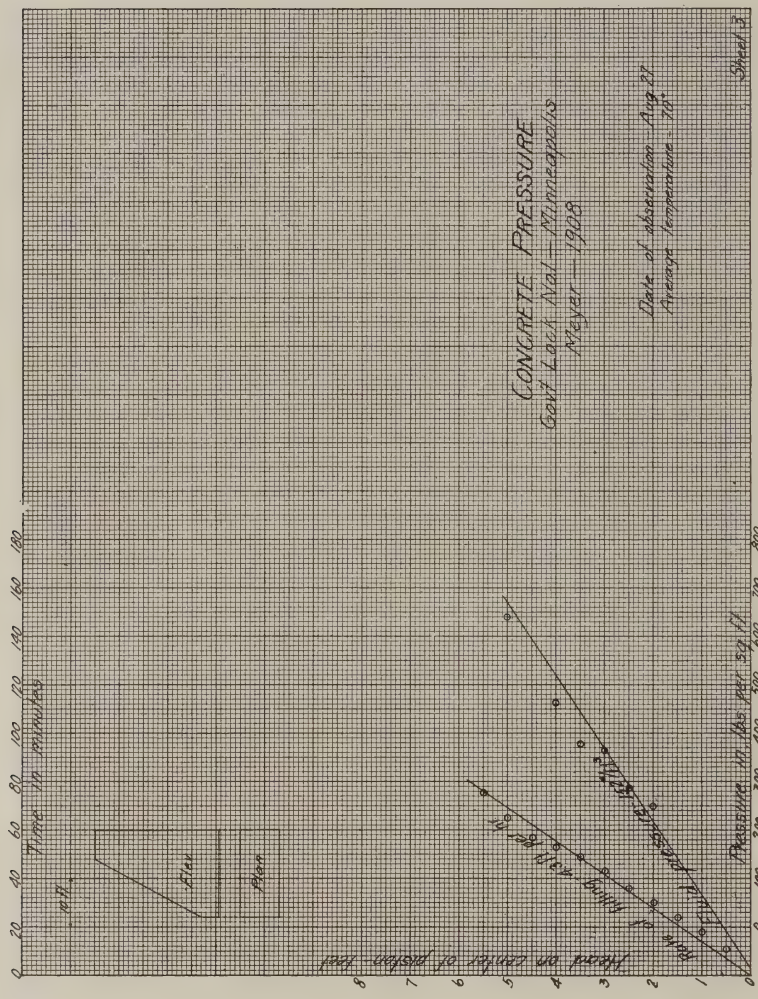
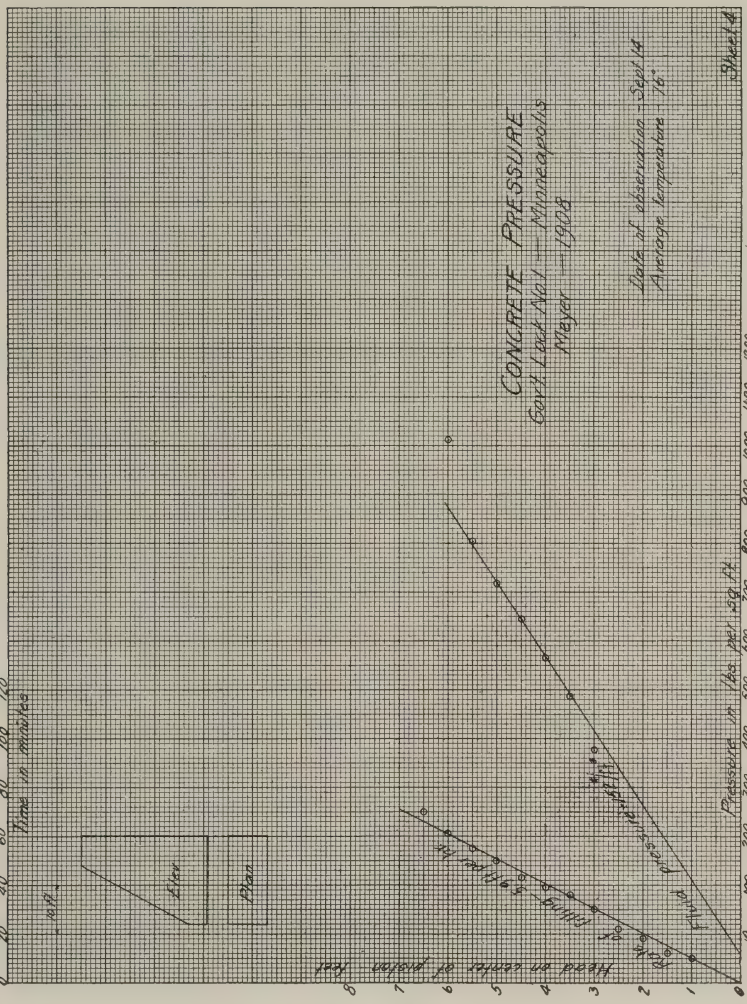
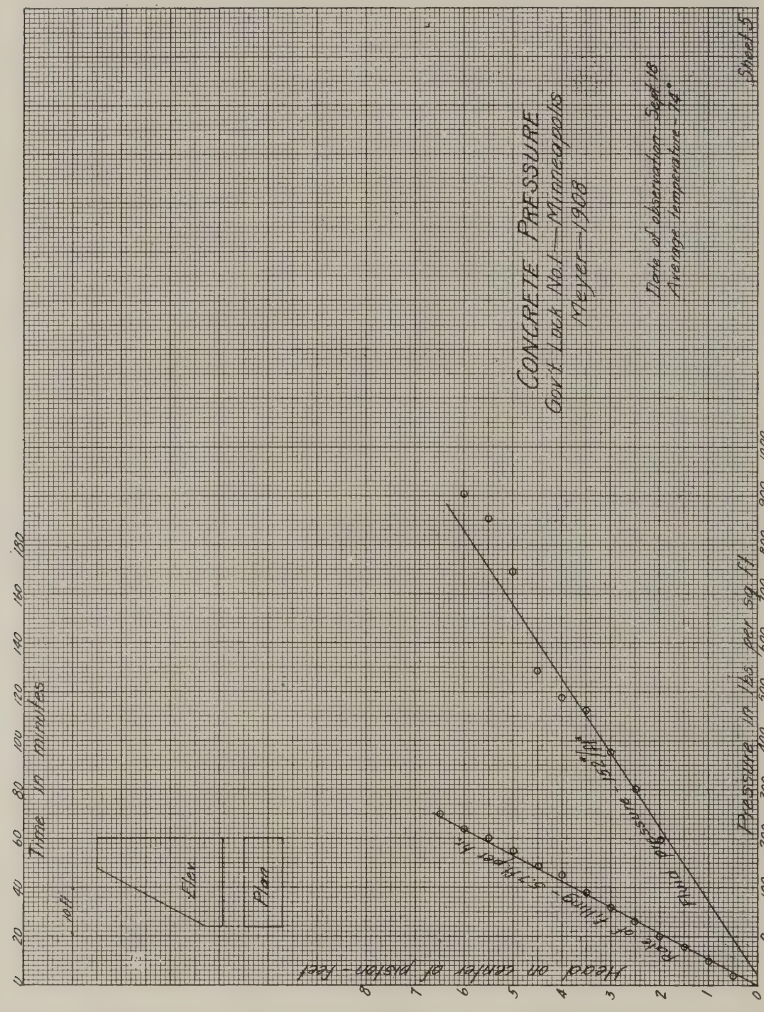
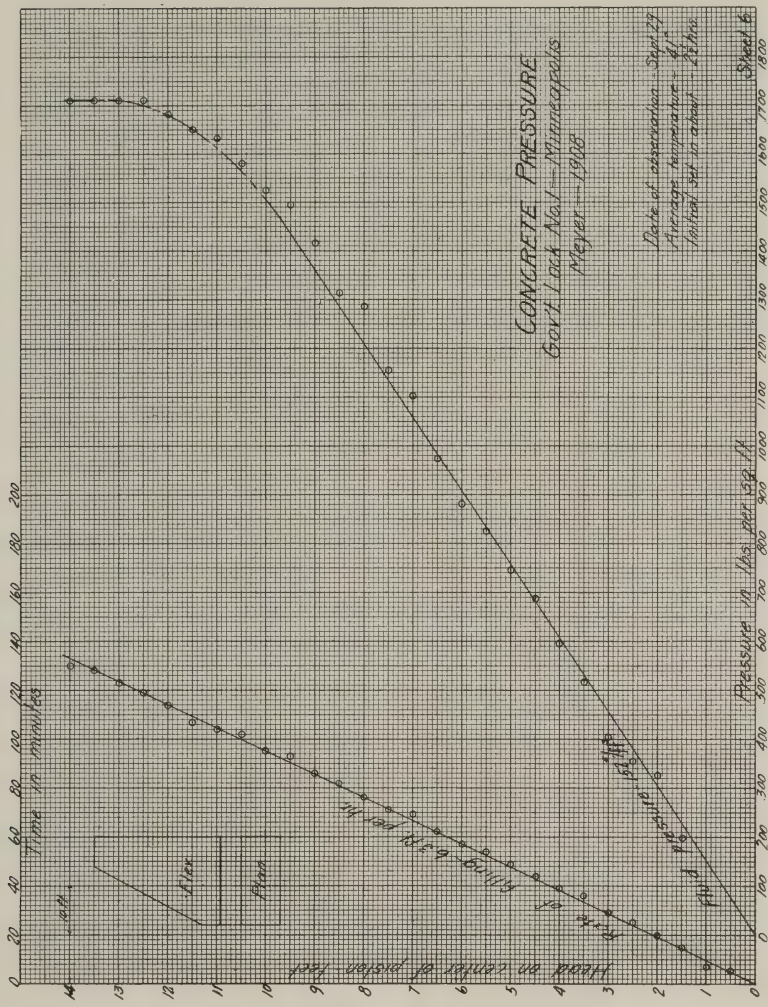
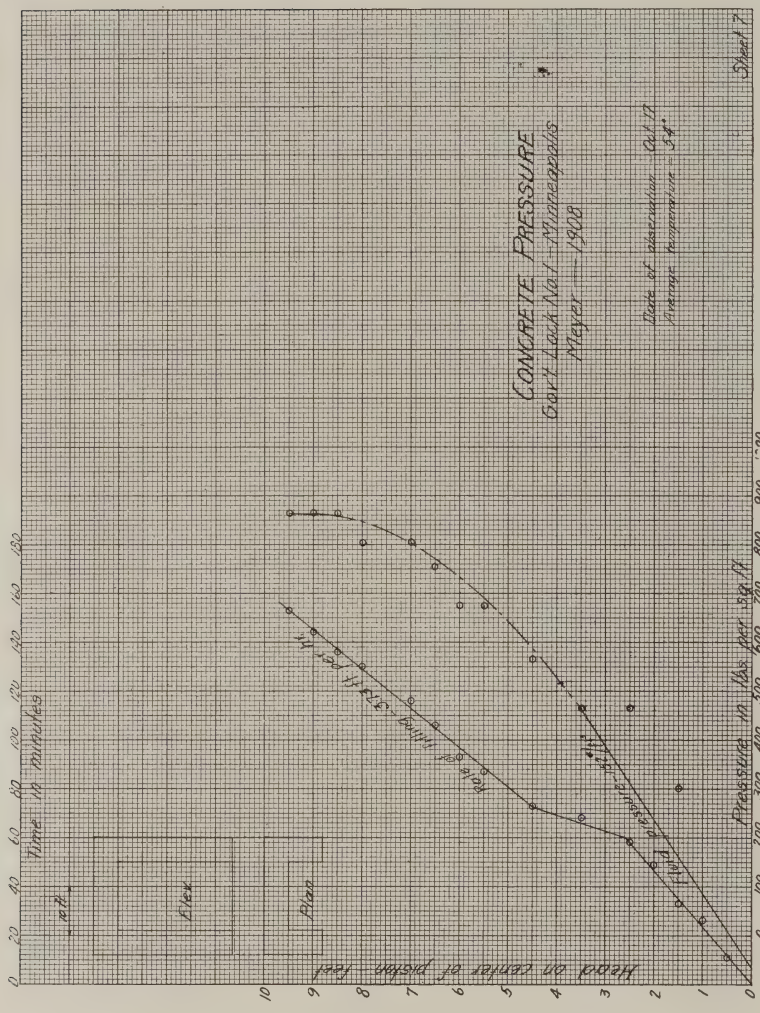
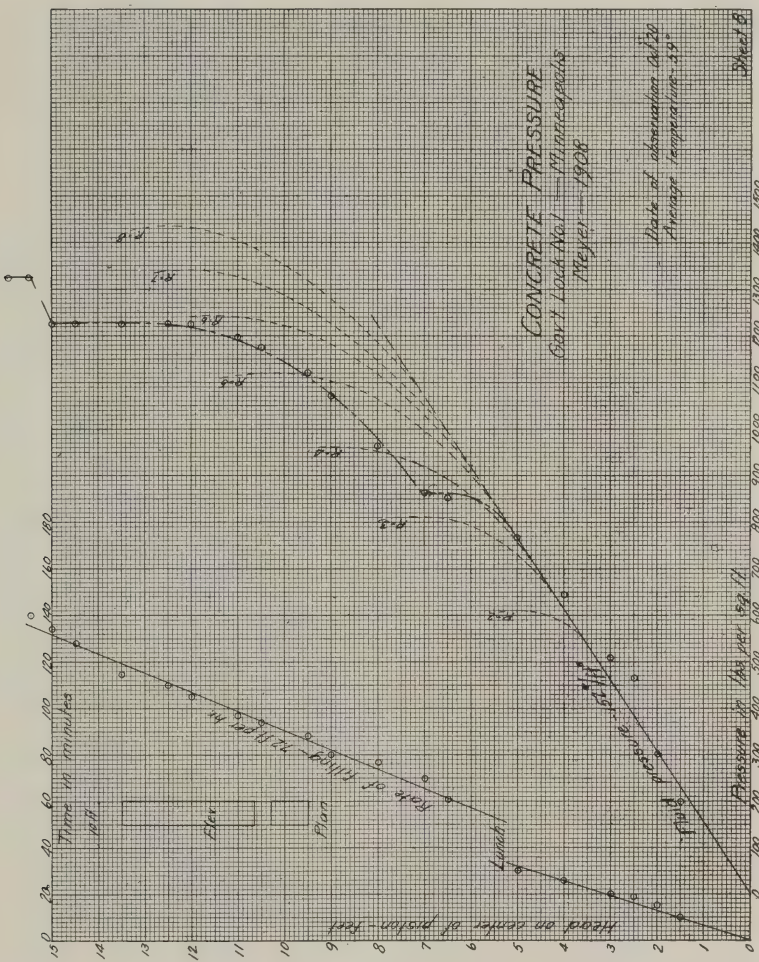

CONCRETE PRESSURE
Cent. Lock, Nal. Minneapolis
Nyer. 1908
Date of observation Aug. 27
Average temperature 70°
Sheet 5
Pressure in lbs. per sq. ft.
Time in minutes
Head or center of pressure feet
Rate of filling wall
Actual pressure
Plan
Elev.

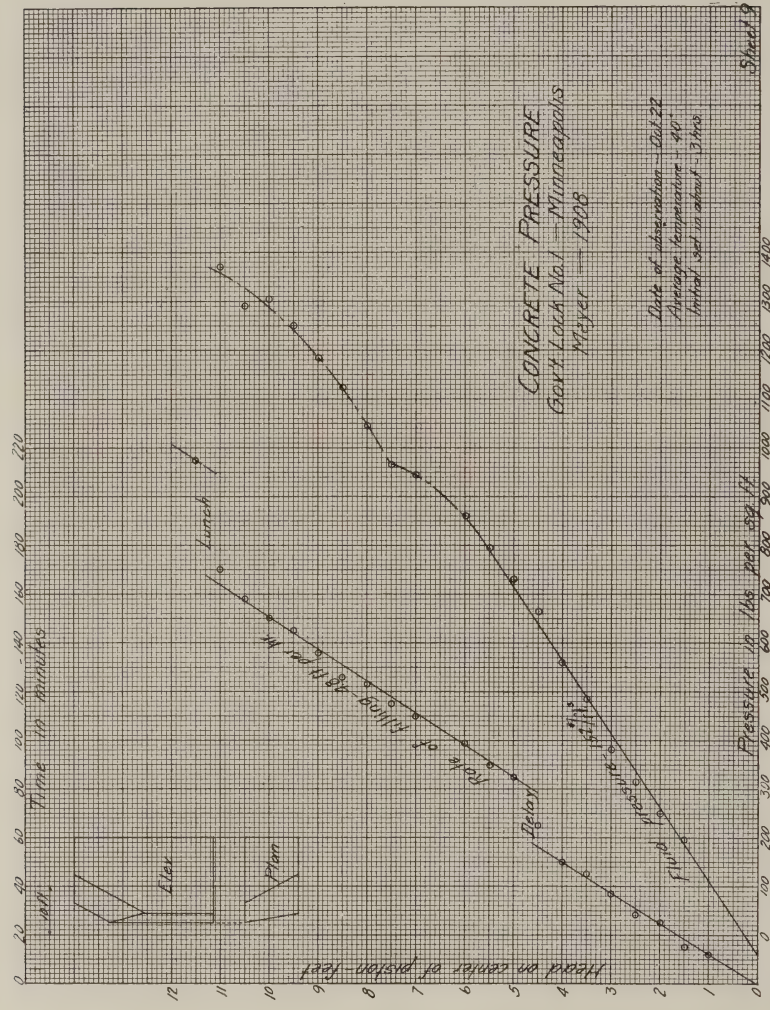

CONCRETE PRESSURE
Sheet 4
Gate Pier No 1 — Minneapolis
Mayer — 1908
Date of observation - Sept 14
Average temperature 74°
Pressure in lbs per sq ft
Head on center of pressure tube
Time in minutes
Elev
Plan


CONCRETE PRESSURE
Gov't Lock No. 1 — Minneapolis
Mayer — 1908
Pressure in lbs. per sq. ft.
Head on center of pressure - feet
Time in minutes
Fluid pressure 24 hrs.
Fluid pressure 6 hrs.
Rate of rise
Plan
Elev.


CONCRETE PRESSURE
Gov't Lock No.1 — Minneapolis
Meyer — 1908
Date of observation Sept 22
Average temperature 61°
Initial set in about 2 hrs
Sheet 6
Head on center of piston feet
Time minutes
Rate of filling barrel per hr
Fluid pressure lbs per sq in
Pressure lbs per sq ft
Filler
Mixer


CONCRETE PRESSURE
Gov't Lock Nat'l - Minneapolis
Meyer — 1908
Sheet 7
Date of maximum 24/7
Average temperature = 54°
Pressure in lbs. per sq. ft.
Time in minutes
Head on center of piston feet
Elev
Plan
Pipe pressure
Hole 8 filling - 372 ft. per hr.


CONCRETE PRESSURE
Gov't Lock No. 1 — Minneapolis
Meyer — 1906
Date of observation 04/20
Average temperature 39°
Sheet 8
Head on center of piston - feet
Pressure per square inch - pounds
Rate of filling - 7.5 feet in minutes
Line of pressure
Line of head
Lower
Upper
Pipe
Pipe


CONCRETE PRESSURE
Govt. Lock No. 1 — Minneapolis
Mayer — 1908
Date of observation — Oct. 22
Average temperature — 40°
Initial set in about 3 hrs.
Sheet 9
Pressure — lbs. per sq. ft.
Time in minutes
Head on center of piston - feet
Lunch
Delay
Rate of filling 8 ft. per hr.
Pressure at first
Pressure at last
Plan
Elev.

# Electricity in the Work of the Corps of Engineers

*BY*

Lieut. W. H. Rose
*Corps of Engineers*

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It is intended that this paper shall answer, to some extent at least, the oft-repeated question of student officers at the Engineer School concerning the course in Electrical Engineering—"How much electrical engineering does an engineer officer need in the work of the Corps?" The writer will endeavor to enumerate the principal applications of electricity in the various branches of work under the Engineer Department and to describe briefly the nature and extent of these applications.

The discussion will be conducted under the following divisions:

1. Seacoast Fortifications:
   - (*a*) General Duties.
   - (*b*) Central Power Plants.
   - (*c*) Transmission and Distribution System.
   - (*d*) Reserve Power Plants.
   - (*e*) Searchlights.
   - (*f*) Torpedoes and Submarine Mines.
   - (*g*) Firing Circuits for Guns.
   - (*h*) Repairs, Purchase of Supplies, etc.
2. Field Operations:
   - (*a*) Sieges.
   - (*b*) Mobile Army.
   - (*c*) Bases and Lines of Communication.
3. River and Harbor Improvements.
4. Miscellaneous.

## (1) SEACOAST FORTIFICATIONS.

### *(a) General Duties.*

The Army Regulations prescribe that the general duties of the Corps of Engineers shall include "the installation of electric power plants and electric power cables connected with seacoast batteries,

and furnishing the necessary electrical supplies connected therewith."

They further prescribe that, "At each post supplied with a fortification electric plant sufficiently large for supplying necessary current for lighting buildings and grounds, the plant may be used for that purpose by the Quartermaster's Department when authorized by the Chief of Engineers, provided that the needs of defense shall have precedence over post lighting or power supply in any case in which both uses are simultaneously desired.

"For this purpose, when funds that are applicable can be spared, the Engineer Department will construct necessary conduits, service wires, etc., to deliver the current to the various buildings and to exterior lights, and the Quartermaster's Department will wire the buildings, furnish meters for officers' and non-commissioned officers' quarters, exterior lamps, etc., and will, in addition to the fuel, material, etc., required to be furnished by it to all fortification electric plants, supply for such plants as may be used for post lighting all material and funds necessary for their repair and preservation."

General Orders No. 183, 1907, War Department, further prescribe that "For the fortifications and their accessories, the Engineer Department will supply and install all necessary electrical appliances and apparatus for furnishing light and power, including rubber matting for dynamo rooms, switchboards and instruments attached thereto, and searchlight equipments, with the exception of the motors permanently attached to the gun and mortar carriages, and except when central electric plants have been installed which provide current for the post as well as the fortifications, in which case the necessary supplies, etc., will be furnished in accordance with the provisions of Army Regulations 1066. * * * It will also, as funds permit, supply reserve lanterns for use in permanent seacoast batteries and fire-control stations in case of failure of electric current."

For fire-control installations, paragraph 1, General Orders No. 72, War Department, 1906, requires the Engineer Department to furnish searchlights and the electric power current required for all fire-control purposes (except that derived from Signal Corps storage batteries installed to operate telautographs), together with electric lamps and other material for lighting all stations, etc.; it will also

furnish and install all wiring, underground or overhead, for lighting and power.

Paragraph 2 of the same order also requires that underground cable lines for communication furnished by the Signal Corps will be placed in trenches or ducts by the Engineer Department. When practicable, any pole lines which have been installed by the Engineer Department for light and power wires may, with the consent of that Department, be utilized by the Signal Corps for any of these wires.

The National Coast Defense Board, better known as the "Taft Board," made the following statements and recommendations in their report, under the heading of Power Plants and Electrical Installations:

The use of electricity in connection with seacoast defense has become necessary for:

1. Current for motors to operate ammunition hoists, in order that the service of ammunition may be equal to the increased rapidity of fire of the guns.
2. Current for the system of range finding, fire control, and direction.
3. Current for searchlights.
4. Current for lighting various parts of the emplacements and range-finding stations.
5. Current for motors for retracting the guns on disappearing carriages.

The foregoing needs of electricity for fortification uses, the use of the fortification plant for post and garrison lighting, the relative advantages and disadvantages of direct and alternating current to motors and searchlights, as well as the distances of transmission, were all carefully and fully considered and discussed by the committee, as a result of which it recommends:

1. That the electrical power for fortification and defense purposes be furnished by an adequate steam-driven, direct-current producing central power plant, all machinery to conform in type to approved commercial standards.
2. That each battery or group of batteries, depending upon local conditions, be equipped with direct-current generators, gas or oil engine driven, installed as a reserve to the central plant.
3. That searchlights, except such as are in close proximity to the central plant, be provided with and operated by self-contained units.
4. That the torpedo casemates be equipped as heretofore with independent power for submarine-mine purposes, as an integral part of the submarine-mine defense.
5. That when alternating currents are essential, they should be obtained, if practicable, from direct current by means of a suitable converter; or if more economical, by a separate alternating unit.
6. That the current from the fortification central plants, when not needed for fortification service, may be used for garrison purposes when such

distribution does not require too large an increase in the size and number of units.

7. That if garrison service requires alternating current, this should be supplied from the central plant, either through a suitable converter or from alternating current units especially installed for the purpose in the central station; such increase, however, and all additional cost due to post lighting, being a charge against the proper appropriation.

8. That uniformity of types and accessories is desirable.

9. That all electrical power plants for the use of fortification shall be operated by the Artillery.

From the consideration of the duties assigned to the Engineer Department contained in Army Regulations and general orders as outlined above, the work of an engineer officer in connection with the electrical installation at a seacoast fort would be as follows:

*(b) Central Power Plant.*

Under this heading would be included buildings, boilers and auxiliaries, engines and auxiliaries, generators, motor-generators where required, storage batteries where required, switchboards and instruments.

The location of the power house will be governed by the considerations of protection from hostile fire, location of the various points to which power is to be supplied, ease of securing coal and water for the boilers, character of foundations and ease of construction. It will be designed with a view to securing the best possible conditions as to light, ventilation, dryness, and cost. Separate rooms should be provided for boilers, for engines, generators and switchboards, and for storage batteries, where they are used. Mimeograph No. 79 requires that storage for at least ten days' supply of coal will be provided.

The Engineer Department will have charge of the purchase, tests, and installation of suitable boilers and auxiliaries, including feed water heaters and pumps, injectors, meters, valves, gauges, fans for forced draft, steam piping, tools, spare parts, etc. The water-tube boilers have the advantage of quick steaming qualities, economy of fuel, ease of cleaning and inspection, and greater safety against explosions, and this type of boiler would probably be selected. Supplement to Professional Papers No. 27 contains specifications for water-tube boilers recommended by a board of engineer officers.

The purchase, test, and installation of steam engines for prime movers will be the next point to be considered. Hitherto these have been of the reciprocating type. However, the recent development of the steam turbine in small and medium sizes will justify its con-

sideration for this purpose. When condensing water in sufficient quantity is available, economy will require the installation of a suitable condenser. The various engine auxiliaries will include steam separators, lubricators, oil filters, tools, spare parts, etc. Specifications for engines are also included in the supplement to Professional Papers No. 27.

The generating apparatus comes next in order. It should be stated at this point that the station equipment should consist of three or four independent units of sufficient size, so that one can be held in reserve for cleaning, repairs, or emergencies. For example, if the total load is 150 kilowatts, four generators, each of 50-kilowatt capacity, could be installed with four engines and four boilers of suitable capacity. Three of the units could then carry the full load, leaving one in reserve. Another combination, and probably a better one, would consist of one 50-kilowatt and two 75-kilowatt generators, the former being held in reserve. In case anything happened to one of the 75-kilowatt machines when the full-load output of the station was called for, the other two could carry the load for a number of hours, each operating at 20 per cent overload. Also, two boilers, each capable of carrying the full load, instead of four, could be installed. These systems offer a further advantage in greater economy, as one or two units can carry the lighter loads, thus working at greater efficiency near their full-load points than a single unit could on the partial load.

If the recommendations of the National Coast Defense Board, outlined above, are followed, the generators will in general be of the direct-current type. When an emplacement or a group of emplacements or the garrison is at such a distance from the central station that the use of alternating current is essential, either of two methods may be pursued. Alternating current may be obtained from direct current by a rotary converter or a motor-generator set, or a separate alternating-current unit may be installed. The conversation method would appear to be somewhat better as giving a more uniform station equipment. The rotary converter is cheaper, more efficient, and occupies less space than the motor-generator set. It is harder to start, requires more skill to operate, and the voltage regulation is not so easy. The motor-generator set seems to have been the choice of constructing officers in the past. This would consist of a direct-current shunt motor, direct connected to a three-phase revolving-field alternator. Step-up transformers would transform the generated alternating current to a proper voltage for

transmission—1,100 volts or higher, depending on the distance. At the receiving substation it would be stepped down to 110 or 220 volts, and would then be reconverted to direct current by another rotary converter or motor-generator set. In the latter case a three-phase induction motor would be used, direct connected to a compound-wound direct-current generator. If the current is to be used for searchlight purposes, a Rosenberg generator would probably be used as affording better current regulation.

The three-phase system is used for transmission on account of being more economical in copper and on account of the simplicity and satisfactory operating qualities of the three-phase induction motor.

Just what shall be the limiting distance in deciding on direct or alternating current for transmission can not be definitely stated. Authorities range from 1,000 to 6,000 feet. A discussion of the question can not be attempted within the limits of this paper. The governing distance will depend largely on local conditions, such as the distribution of the load, and must be worked out separately for each place.

The standard commercial voltages for direct-current generators are 125, 250, and 600 volts. Here, again, the choice of the proper voltage will depend upon the distribution of the various portions of the load over the area to be supplied with power. If the distances are too great for the 220-volt system, alternating current will probably be used instead of 600-volt direct current. Reference is made, in this general connection, to Professional Papers No. 27 and supplement thereto, Mimeographs Nos. 13, 39, 41, 75, 76 and 91, and their supplements; Major Winslow's lecture on Coast Defense, and Occasional Papers No. 13, Engineer School.

The next point in the central station for consideration is the switchboards with the proper safety and protective devices, measuring and recording instruments, switches, etc., for the control and distribution of the power. The number and arrangement of panels and of the various instruments and switches they contain will depend upon the number of generating and converting units, feeder circuits, etc. Uniformity of all apparatus and of its arrangement is desirable as far as possible, so that when Coast Artillery troops are shifted from one station to another they will be familiar with its operation.

In case the garrison is supplied with current from the fortification plant, a portion of the plant will have to be kept in continuous

operation, unless a storage battery is installed as part of the equipment. Accumulators are expensive, bulky, require a great deal of attention and expert handling, and their life is not long unless they receive the best of care. They have been decided against as auxiliaries for reserve purposes, and it would not seem advisable to install them for post lighting unless under exceptional circumstances. The engineer officer in charge of construction would consult with the proper authorities of the Quartermaster's Department on the subject of garrison lighting, as all additional costs due to this use of the fortification plant are charged against appropriations pertaining to that Department.

*(c) Transmission and Distribution System.*

The cables of the transmission and distribution system will generally, from considerations of safety, be laid in underground conduits connecting the central station with the various emplacements, searchlights, fire-control stations, etc. Where overhead lines will not be subject to possible disturbance, pole lines will be used with insulated, water-proofed cables for the sake of economy. Underground cables will be rubber insulated, lead covered and armored or unarmored, as the circumstances of the case may require. In tropical countries rubber deteriorates rapidly, and paper or cambric insulation will probably be used. Where armored or unarmored lead-covered cables come in contact with or are exposed to the drip from concrete, the lead sheaths must be protected by a layer of rubber-impregnated tape. Specifications for two grades of cable with methods of testing have been prepared by Major Taylor, of the Engineers, and will be found in Mimeograph No. 110. The number of separate ducts in the conduit will depend on the number of cables to be laid in them. Care should be taken to have a sufficient number in the original installation, to save the extra expense of adding them later if necessity should arise. Manholes should be provided at the proper points. (See 47th Supplement to Mimeo. No. 48.)

Underground cable lines for communication furnished by the Signal Corps will be placed in conduits by the Engineer Department.

The transmission cables from the central station run to distributing panel boards in the several emplacements, and from these panel boards branch circuits lead to the various portions of the emplacement. Various schemes have been devised for the arrangement of these branch circuits. In the earliest installations ordinary insu-

lated, rubber-covered wires were used, held away from the walls by insulators and passing through them in pipe conduits. This system was unsatisfactory, as the seepage water from the concrete disintegrated the rubber insulation. Pipe conduits were then tried, but it was found impossible to keep the water out of them. Small lead-covered, rubber-insulated cables, single or twin conductor, are now used and in the latest types of batteries are simply fastened to the walls by insulators and left exposed so as to be entirely visible, or, in exposed situations, or in rooms with low ceilings, where they would be liable to damage by unscrupulous or malicious persons, they are protected by flexible armor or iron conduit. Mimeograph No. 87 contains the recommendations of the Board on Electrical Installations on this subject. The location of the lights are given in the various plans of the different emplacements. Wire guards for the protection of the bulbs are advisable.

To prevent danger from grounded circuits, the different sections of the trolley rails for the ammunition service should be bonded together by metal connectors and the rails bonded to the metal of the ammunition hoists. (See 27th Supplement to Mimeo. No. 46.)

To secure speed control of the motors used for traversing the guns, the Ordnance Department formerly used the variable voltage method known as the Ward Leonard system. This involved an additional motor-generator set and switchboard, which were located in a room in the emplacement known as the ordnance motor-generator room, and furnished by the Ordnance Department. The same Department was supposed to wire the switchboard and motor generator. The Engineer Department installed them and connected the switchboard with the power cables. This Department also furnished and installed a multiple cable extending from the switchboard to a junction box in the gun well. From this junction box the connections to the motors were made by the Ordnance Department. In this connection, reference is invited to the second supplement to Mimeograph No. 66 and to Mimeograph No. 67. Guns are now traversed by hand, but a return to the above-mentioned system is not improbable.

The Engineer Department furnishes and installs portable lights for use on gun platforms, mortar pits, etc. (See Mimeo. No. 92, Supplements 2 and 3.)

The Signal Corps furnishes storage batteries for telautographs, and the power for these instruments is transmitted over separate wires, independent of emplacement lights, hoists, motors, etc. The

batteries are charged from the central station, but the entire power network for the instruments from the switchboard in the central station, through the battery to the instruments, is furnished by the Signal Corps.

*(d) Reserve Power Plants.*

It is evident that the central station is subject to destruction or at least temporary shut down by hostile fire. It may be compelled to shut down by reason of accident or necessity for cleaning or repairs. Furthermore, it takes considerable time to get up steam, and in case of sudden attack the electrical system would be helpless for several hours at least. For these reasons the Taft Board has recommended "that each battery or group of batteries, depending upon local conditions, be equipped with direct-current generators, gas or oil engine driven, installed as a reserve to the central plant."

As stated previously in this paper, the accumulator or storage battery was first used as a reserve. For a number of reasons these were unsatisfactory. During the last few years Major Taylor, of the Engineers, has been experimenting with a number of different types of gas and oil engine driven generating sets. Two types have been selected for trial, and about 160 sets have been manufactured or are contracted for. The Dock gas engine is a 5-cylinder, 6-inch by 7-inch, engine, running at a speed of about 750 r. p. m. at full load. This is direct connected to a 25-kilowatt, compound-wound, inter-pole, direct-current Sprague generator. The engine is provided with radiator and motor-driven fan for keeping down the temperature of the cooling water. The total weight of the set is about 4,000 pounds.

The General Electric set is composed of a 4-cycle, 4-cylinder, single-acting, vertical gasoline engine, direct connected to a direct-current generator of 25-kilowatt capacity, 110-125 volts, running at 560 r. p. m. Both sets are capable of operating their generators at full load indefinitely and at 25 per cent overload for two hours, furnishing in each case 2.5 kilowatts additional for operating radiator fans.

These reserve plants may be located in an emplacement or in a small separate power house. Mimeograph No. 116 shows a design for a power house for two Dock sets, which with slight modifications can also be used for the General Electric type.

*(e) Searchlights.*

The Endicott Board, in its report submitted in 1886, recommended the installation of 200 searchlights. The Board of Engineers in

1901 recommended 344, at an estimated cost of $600,000. The Taft Board submitted estimates of $2,897,000 for searchlights for home ports, $589,000 for insular ports, and $228,000 for Isthmian Canal ports.

The number and location of searchlights at any particular place will depend upon local conditions and the purpose of the particular light, whether for searching or illuminating. However, so far as location goes, the lights, position-finding stations, and batteries are mutually inter-dependent and should be considered together.

For coast defense work the 36-inch and 60-inch projectors are the adopted sizes. The Taft Board recommends that "except when in close proximity to the central plant searchlights will be provided with and operated by self-contained units." In the past they have been operated by a variety of units—some directly from central stations; others by motor-generator sets receiving their power from central stations or commercial lighting lines; others by independent gas or oil engine plants and others by portable boilers and steam turbine driven generators. In general, it would seem that operation from the central plant and from motor-generator sets have been the most satisfactory, though no considerable trouble has been experienced with the independent internal combustion engine plant. This latter type would seem to be the one favored by the Taft Board. The Dock and General Electric gasoline engines mentioned previously under reserve power plants are excellently adapted for searchlight purposes. The compound generators are not well suited for searchlight operation, as they do not possess the inherent current regulation which is desirable. A comparatively new type of generator, called the "Rosenberg," from its inventor, Dr. E. Rosenberg, of Germany, has been developed, which seems to be exceptionally well adapted for searchlight work. A brief description of this generator will be found in Artillery Notes No. 31.

For the satisfactory operation of searchlights two conditions are essential—a practically constant current for the arc and a practically constant voltage for the training motors. If compound generator be used for both sources, the constant voltage condition may be fulfilled, but the constant current for the arc can only be obtained by the introduction of a regulating rheostat, introducing large power losses and the necessity of hand regulation. If a constant current generator be used, as the Rosenberg, its voltage regulation curve will drop rapidly with increase of load, and training motors and

controller will not operate satisfactorily. We see, then, that the requirements of the arc and of the training motors are mutually contradictory. It will therefore be necessary to provide for both constant current and constant voltage power at the searchlight.

If a transmission line extends to the light from our central station, which will be operated at constant voltage, training motors can be connected directly to this line, and we can operate a motor-generator set with a Rosenberg generator for the arc current. If we use an isolated gasoline-engine set, we can have a compound generator connected to the engine operating at constant voltage. The training motors will be supplied directly by this generator. For the arc we can introduce a motor generator consisting of a shunt motor and Rosenberg generator. When gasoline-engine sets are used for isolated searchlights, where the only constant voltage current required is that for the training motors and control apparatus and, perhaps, a few incandescent lights, the Rosenberg generator can be direct connected to the gasoline engine with a small direct-current constant voltage generator mounted on the same shaft. This scheme has not yet been tried, but will be much cheaper in first cost than the motor-generator system, as well as more economical in operation.

The searchlight itself will generally be movable, though for coast defense work the extent of its movement need not be large. At Fort Monroe, in the joint Army and Navy Maneuvers of 1905, some were placed on cars running on short lengths of track which led from the beach to concealed shelters. Towers are now preferred.

The light should have an elevation of at least 20 feet and, except for the projector itself, should be protected by means of a parapet. If the light is fixed, on account of the possible location being limited, a disappearing light with all appurtenances under cover has been recommended.

The power unit may be fixed or portable, but will usually be fixed. The power house referred to previously, described in Mimeograph No. 116, will be suitable for its housing. Thorough protection for the power house will be essential.

In the apparatus for the distant control of the searchlight continual improvements have been going on for a number of years. Two new control systems are now being experimented with—one recently developed by the General Electric Company; the other the invention of Mr. LeBlanc, electrical engineer in the New York

district office. Both seem to be better than the old systems, but it is not known at this time which will be adopted. The General Electric controller has the advantage of more rugged construction and will probably be the type selected for coast defense searchlights. The LeBlanc is very easily adapted to existing lights whose control apparatus is worthless.

Mimeographs Nos. 39, 76 and 91, with their supplements, Artillery Notes No. 31, and Occasional Papers No. 13, Engineer School, are referred to as containing more detailed information on searchlights, their installation and operation.

*(f) Torpedoes and Submarine Mines.*

Formerly this entire branch of coast defense work was in the hands of the Corps of Engineers. A few years ago the installation and operation of the mines was transferred to the artillery as being so closely connected with the gun defense as to be practically an integral part of it. The Engineer Department constructs the mining casemates, conduits connecting casemates to the shore, cable terminals on shore, torpedo storehouses, cable tanks, loading rooms, torpedo wharves, tramways, range stations and plotting rooms. Mimeographs Nos. 32, 48 (Supplements 31 and 43), 72, 80, 92, and 100 give details of construction and arrangement of mining casemates, torpedo loading rooms, cable tanks, etc.

*(g) Firing Circuits for Guns.*

When the guns are fired by electricity from a distance, special batteries or magnetos independent of the main power and lighting circuits are used.

*(h) Repairs, Purchase of Supplies, etc.*

Yearly appropriations for the purchase of electrical supplies for seacoast fortifications are made by Congress. The artillery engineer at each post submits a requisition to the Chief of Engineers for material needed, which is purchased and issued by the district engineer officer. The latter is also required to make periodical inspections of the entire electrical installation in company with the commanding officer of the post and the artillery engineer. Minor repairs are made by the artillery. Any extensive repairs or alterations are made by the Engineer Department.

(2) FIELD OPERATIONS.

It is obvious that in this division of the subject our discussion

must treat, not of the past and present work of the Corps, but of the possibilities in the way of applying electrical apparatus to the varied needs of our forces in sieges, in mobile armies, and in bases, depots, and lines of communication in future wars.

*(a) Sieges.*

In defensive siege operations the searchlight will have functions equally important with those it fulfills in our coast defense forts. They were extensively used by the Russians in the defense of Port Arthur, though not nearly so effectively as was possible if more practice had been had in handling them and if a greater number had been available. Professor A. von Schwartz, in his article on "The Influence of the Experience of the Siege of Port Arthur upon the Construction of Modern Fortresses," states that, in his opinion, the searchlight will be as indispensable in the siege warfare of the future as the siege gun, the rifle, and the spade.

He summarizes the general duties to be performed by them as follows:

1. By lighting distant areas, to embarrass the movements of larger bodies of hostile troops and disclose the transportation of freight and the movements of trains, as well as work in progress on the line of investment.

2. By lighting the nearest approaches to hamper mining and sapping work and disclose the approach of assaulting detachments.

3. By forming lighted zones to impede the work of hostile searchlights.

He recommends the following plan for the disposition of searchlights in the main line of defense:

1. At each fort a strong searchlight for distant lighting with a diameter between 36 and 45 inches.

2. A similar searchlight at each intermediate redoubt.

3. At each rear intermediate caponiere of the forts two searchlights with a diameter from 24 to 32 inches to flank the intervals.

4. Four projectors with a diameter from 16 to 24 inches in the intervals between the forts to light the nearest approaches to the intervals.

5. In case there is a second line of defense, which must be placed so that the first line can be seen from the second and covered by its fire, searchlights must be provided for the second line to light the first line in case the enemy breaks through it. A few very strong

searchlights are needed here capable of giving good illumination at about 3 miles.

It is of course necessary that all lights used in siege operations be protected as far as possible. Lights located in forts and redoubts will be practically fixed in position. Those in the intervals will be portable. The same general methods of securing portability, supplying power, etc., will be used as previously described for projectors used in coast defense. The self-contained portable field set, either of the automobile or Field Artillery type, can be used to good advantage in siegework.

On the offensive, searchlights will have similar uses to those outlined above. For hindering working parties, observing the effect of fire, neutralizing the effect of opposing searchlights by crossing beams, preventing offensive action by the besieged, etc., their value is apparent. They will be of more value in the distant than in the closer siege operations.

For more extended study of this branch of our subject reference is made to the translation of the article by Von Schwartz mentioned above and to Major Kuhn's report on the Russo-Japanese War.

The Russians constructed an electric fence about 5 miles long covering the sector where the main Japanese attack was made. It consisted of five wires supported on insulators mounted on short stakes, the wires carrying a current of 3,000 volts. It was not a success. The Japanese insulated the handles of their wire cutters and cut the wires. The Russian engineers claim, however, that the electric fence promises to be one of the most powerful weapons of defense, but that it must be prepared in time of peace, when proper precautions for its location, insulation, and concealment can be taken.

(See Von Schwartz, Major Kuhn's Report, and Occasional Papers No. 33, Engineer School.)

The engineers will also be able to utilize electricity to good advantage in the operation of the railways connecting the city with the enciente and the line of forts and of the belt and portable roads. At Port Arthur the horses were killed or eaten before the end of the siege, and the lack of railways was severely felt. However, Von Schwartz states that he is convinced that the use of steam traction would have been of doubtful benefit, as the enemy was able to locate their vehicles by the noise, and a steam locomotive would have been much easier located by the puffing and the sparks from the smokestack. Electric power would be especially fitted for this work and

would be readily available in the street railway systems of most modern cities. Electric vehicles for traction purposes are now being developed and would find a valuable field in siege operations, both offensive and defensive. Attention to this point will be invited later in connection with the automobile searchlight truck.

Another duty that engineer officers would be given is the supervision of power plants, street railways, lighting systems, etc., in the besieged city. These would be operated by their regular skilled, civilian engineers, but in a city under siege their general supervision, and especially their utilization for all military purposes, would be entrusted to the engineers.

In offensive operations work of this class will be somewhat more restricted in extent, though power plants of outlying suburbs, factories, etc., that lie within the besiegers' lines will be capable of considerable use in the repair shops of the engineer park, and might govern its location.

In general, we may say that there will be numerous opportunities for the use of electricity in siege operations, and the extent to which these opportunities are taken advantage of will depend upon the knowledge and ingenuity of the officers on duty with the besieged or besieging forces.

*(b) Mobile Army.*

With a mobile army somewhat more restricted opportunities will be presented. Searchlights will have a large field of use for the same general purposes as outlined in siege operations. With the mobile army the entire searchlight unit must be self-contained and completely portable. Two different types of outfits for field use are now being developed by the Engineer Department and have been referred to in a previous portion of this paper.

The first type is being developed for the service of the Field Artillery. It consists of two wagons drawn by six-horse teams, the drivers to be mounted. One wagon contains an 8-kilowatt gasoline-engine power plant complete with switchboard and radiator, all to be covered by a canopy top and side curtains. This wagon is to be known as the power unit of the outfit. The second wagon, known as the projector unit, carries one 30-inch electrically controlled searchlight, the drum of which is to be detachable to reduce the strains on the trunnion arms while under transportation. This unit will also contain a reel with 500 feet of supply cable and 500 feet of controller cable. Wheels, axles, and draft gear of both units

are the standard 3-inch limber and caisson type of the Field Artillery.

The second type, which is now practically ready for test by the Engineer Department, will be known as the "Auto Searchlight." In this unit there is a 15-kilowatt, 5-cylinder, Dock gasoline-engine generating set, mounted on a "Couple-Gear" truck, designed especially for the service. The truck is driven by direct-current series motors, one mounted in each wheel, receiving current from the main generator. The drive system is exceedingly powerful and very efficient, and the truck has already been driven without difficulty through 12 inches of mud. The generating set can furnish 85-volt current in capacity up to 24 kilowatts (for short periods) for the searchlight service alone, for the propelling service alone, or for the combination of the two. The tractive effort of the truck is so large that it will make an exceedingly valuable addition to the engineer equipment for hauling service in case of emergency.

The truck is designed to make three miles per hour on hard, level roads with motors in series-parallel and 85 volts on the bus-bars. With all motors in parallel and 85 volts impressed a speed of about eight miles per hour is obtainable. The last step in the controller throws a shunt across the field of each motor, thereby weakening the field and increasing the speed. The present installation of shunts will give a speed of from 10 to 11 miles per hour on level roads at 85 volts impressed. All of these speeds may be increased by voltage regulation of the generator. It is contemplated that new shunts will be connected, so that an emergency speed of 14 or 15 miles per hour can be attained with 85 volts on level roads. The light itself, with regulating rheostat, controller, and cable, is carried on a platform on the rear part of the truck.

Thorough protection for the complete unit will be essential. The Germans are experimenting with a collapsible wooden tower carried complete on one wagon, by means of which a 24-inch light can be elevated to a height of 20 feet. The advantages of this device for protection purposes are obvious.

The magneto exploder, to be used in demolitions, blasting in military road making, etc., is another application of electricity that will be extensively used in field operations.

*(c) Bases, Depots, and Lines of Communication.*

At bases and depots, which will usually be located at some city,

electricity from commercial plants will be utilized for lighting and power purposes.

On lines of communication electric railways conveniently located will be used for the same purposes as steam railways.

### (3) RIVER AND HARBOR IMPROVEMENTS.

#### *(a) Locks.*

At locks the opportunities for electricity come in the operation of the gates and valves and the lighting of the locks, lock keepers' houses, etc.

With the exception of the lock in the Mississippi River at Moline, Ill., no examples of electrically operated lock gates in this country are known to the writer. The gates of the lock just referred to are each operated by a 7½-horsepower, three-phase, sixty-cycle induction motor located in a low, concrete housing on the fill back of the adjacent lock wall. Each motor is geared to a steam-shovel sprocket chain, which operates a spar that is pin connected to the leaf.

Electrically operated gates are used in Holland in the large locks at Ymuiden, in the Teltow locks in Germany, in the locks of the Lachine and Cornwall canals, Canada, and in the Canadian Sault Ste. Marie lock. In the latter case a 25-horsepower motor operates a leaf about 37 feet by 40 feet. In the installation of a new lock at Sault Ste. Marie, under a project adopted by the River and Harbor act of March 2, 1907, electrically operated gates are now being considered.

The main disadvantage of electricity in this connection is the fact that the majority of our locks are drowned out at flood stages of the rivers, which of course prohibits the installation of electrical apparatus in them. Where this condition does not obtain, the advantages of this system would probably be sufficient to call for its installation. It is understood that the locks in the Panama Canal are to have electrically operated gates.

Valve operation by electricity will be practicable under the same conditions. The feed gates for regulating the supply of water in the summit level of the Dortmund-Ems Canal, in Germany, are operated by electric motors.

Canal haulage by electricity has been tried in this country in place of animals and steam towboats. It was first used in the Erie Canal about 1893. In recent years experiments have been carried out on

the Ohio State canals between Cincinnati, using electric locomotives or cars driven by three-phase induction motors and running on tracks parallel to the canal. These experiments were very satisfactory and indicated that for a traffic in excess of 2,000,000 pounds per year electric haulage was cheaper than animal haulage or steam towboats. At recent experiments at Schenectady two boats weighing 600 tons were hauled without difficulty at a speed of 4¼ miles per hour by an electric locomotive.

For the handling of boats in locks electricity is applicable and frequently used. This method is to be used at the Panama Canal. Other applications of electricity will be in the lighting of tugboats, snagboats, dredges, etc. In general construction work executed by day labor the opportunity for its employment will be numerous. Motor-driven pumps, air compressors, cranes, hoists, derricks, concrete mixers, etc., are in daily use by contractors all over the country. They consume no power except when actually in operation, occupy comparatively little space compared with an engine and boiler, are easily moved, require no long steam pipes, a single cable being their only connection with the source of power; are inexpensive in first cost and economical in operation.

Another duty of the Corps of Engineers, and one that in future promises to involve the most extensive application of electric engineering in the work of the Corps, is the development of water power in connection with the improvement of rivers for navigation. A very large project of this kind—namely, the power development of the Tennessee River by a lock and dam a few miles below Chattanooga—has already been placed under the supervision of officers of the Corps. Another very important proposed hydro-electric power development in connection with that portion of the Tennessee River from Elk River Shoals to Florence Railway Bridge, in Alabama, is the subject of a report by a board of engineer officers appointed by Special Orders No. 8, War Department, Office of the Chief of Engineers, March 9, 1907.

### (4) MISCELLANEOUS.

#### *Light-Houses.*

The following is quoted from "Military Laws of the United States:"

The President shall appoint two officers of the Navy, of high rank, two officers of the Corps of Engineers of the Army, and two civilians of high

scientific attainments, whose services may be at the disposal of the President, together with an officer of the Navy and an officer of Engineers of the Army, as secretaries, who shall constitute the Light-House Board.

The President shall cause to be detailed from the Engineer Corps of the Army, from time to time, such officers as may be necessary to superintend the construction and renovation of light-houses.

The Light-House Board shall cause to be prepared by the Engineer secretary of the board or by such officer of the Engineers of the Army as may be detailed for that service, all plans, drawings, specifications, and estimates of cost of all illuminating and other apparatus, and of construction and repair of towers, buildings, etc. * * *

Among the various illuminants for light-houses used at the present time the following are the most important:

1. Mineral oil, with burners and wicks.
2. Mineral oil, with incandescent mantles.
3. Illuminating gas, with incandescent mantles.
4. Acetylene, with incandescent mantles.
5. Electricity.

Electricity was first used as a light-house illuminant in England in 1858. Five years later the French, after extended experiments, installed an electric light in one of their light-houses. In 1873 there were eight of these lights in the world—two in France, four in England, one in Egypt, and one in Russia. The writer has been unable to find any definite reference to electric light-houses in the United States previous to 1883, when the noted tower light-house was built at Hell Gate, New York Harbor. This contained nine electric arcs, each of 6,000 candlepower. The light was so intense that the navigation interests claimed it was dazzling to the pilots and made shadows look like obstacles, so in 1886 its use was discontinued, and the tower was torn down. In 1888 there was one electric light-house in the United States, located at Sandy Hook. The report of the Light-House Board for 1908 speaks of nine electric arc lamps now in use. The only light-house of any considerable size in the United States employing electricity as an illuminant is the one located at the Highlands of Navesink, New Jersey, forming part of the system for New York Harbor.

The use of electricity for light-house purposes is not looked on with any great degree of favor in this country, the preferred illuminant at present being mineral oil vapor with incandescent mantles.

Electricity has the disadvantages of requiring expert attendance in the generating power plant, greater cost, difficulty of installation

on isolated rocks, etc., unsteadiness of light due to flickering of arc caused by defects in carbon or poor current regulation, and necessity for duplicating all parts of generating machinery to provide against accident. Nevertheless, we find it in quite extensive use abroad, as is evidenced by the fact that, in 1897, the French had thirteen electric light-houses in service with a number more projected. In the same year the British Government completed the Penmarch light with twin electric arc lamps giving a candlepower of 35,000,000. This is the most powerful light in existence.

In 1885 the British Government created a commission to inquire into and report on the relative merits of electricity, gas, and mineral oil as illuminants. The commission found that the electric light stands first in the rank of light-house illuminants. It claimed that for first-class points of coast lighting nothing could be more desirable, if expense be no consideration, on the ground that its range, definition, and when a distinctive character is employed, as group flashing, its superiority to all other modes of illumination pronounce its excellence and preeminence. The committee declared mineral oil to be the most serviceable, safest, most economical, easiest for storage, equally available for rock, floating or coast lights, and that it did not require machinery or skilled labor for its production.

Electricity was therefore recommended for salient headlands, important landfalls, and wherever a powerful light is required.

Ribiere, chief of the French light-house service, in a recent book on light-houses, recommends the electric light for the same purposes as above outlined and further states that no sacrifices should be avoided in making the light as powerful as possible. Consequently the establishments should be frequently renewed to keep pace with the progress of improvements in electrical and lighting apparatus.

It would seem, therefore, that notwithstanding its obvious disadvantages, electricity possesses sufficient advantages to justify its consideration, at least in future light-house work.

As to the type of electric light to be employed, it will be recognized that the same reasons that require a steady, powerful light, maintaining its location in one spot for searchlight work, call for the same qualities in a light-house lamp.

The incandescent lamp is not well suited, as the form of the luminous element in a long filament renders it unsatisfactory for optical purposes with the lenses now in use. The incandescent light has

been used, however, in floating buoys, notably in Lake Michigan during the Chicago Exposition, with marked success, and in Gedneys Channel, New York Harbor. The latter system was installed in 1888 and removed a few years ago on account of the trouble caused by ships' anchors fouling the supply cable connecting the buoys. Pintsch gas-lighted buoys were installed in place of the incandescent lamp buoys. Direct-current arcs are not very suitable, because the negative carbon partially masks the positive crater, giving a rather irregular curve of light distribution. Several lights of this class are, however, still extant in Europe.

The most satisfactory electric light for light-house purposes is the alternating-current arc, with cored carbons, the core containing various alkaline silicates that have been found to improve the quality of the light. Here both carbon tips are luminous, and we have a symmetrical curve of light intensity. Optically the light is considered as emanating from two circular, plane surfaces, parallel to each other and perpendicular to the axis of the carbons. In the flaming arc recently developed, the arc itself, instead of the electrodes, is the luminous portion. This luminosity is secured by salts of calcium or magnesium in the carbon or its core. The abundant fumes and their corrosive effects are serious disadvantages, but in France it is considered that this mode of lighting is capable of great improvements in the future.

Three different currents are employed by the French engineers—30, 60, and 120 amperes. Special types of alternators are employed, and it is claimed that the 30 and 60-ampere arcs operate very regularly, preserve the form of two plane circular faces parallel to each other and perpendicular to the axis of the carbons, and are very stable. More trouble is experienced with the 120-ampere arcs.

For descriptions of the French light-house system, with details of lamps, regulating apparatus, alternators, etc., reference is made to "Phares et Signaux Maritimes," by C. Ribiere, chief of the French light-house service.

*Building Construction and Superintendence.*

Engineer officers have had no small amount of this class of work to do in the past, and it is not improbable that they will have much of it to do in the future.

Most modern buildings of large size contain their own power plants for generating electricity to supply light, elevators, ventilating fans, etc. As examples of two buildings with independent power

plants now under the superintendence of engineer officers, the Municipal Building of the District of Columbia and the State, War, and Navy Building, both in this city, are enumerated.

In the former building two 150-kilowatt and one 50-kilowatt direct-current generators, direct connected to reciprocating engines, are used to supply power for the various lights, motors, etc., in the building. In the latter case steam turbines are used for prime movers.

*Other Duties.*

An engineer officer is a member of a committee of landscape architects in connection with the preservation of natural scenic effects at Niagara Falls. This committee has to deal with the regulation of the various power companies under their permits from the National Government for manufacturing and distributing electrical power.

It will be seen from the foregoing incomplete enumeration and description of the duties of Engineer officers involving electrical application that a knowledge of electrical engineering by the officers of the Corps is essential to a proper performance of those duties. The Corps must keep pace with the rapid progress of science, and in no branch of science is this progress more marked than in electrical engineering and its various application to civil and military engineering.

# Notes on Regulation Works, Tennessee River System

*BY*

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The Tennessee River system is an example of stable regimen. The banks are firm. The bottom is usually a cemented gravel with rock at moderate depth. The proportion of rock bottom increases rapidly as the stream is ascended until, in the upper reaches, a large share of the bottom is solid rock. So stable is the regimen of this river that resurveys are, in general, unnecessary to determine the conditions at any point already surveyed. Movement of material along the bottom is slight and very slow. This feature has an important bearing upon regulation works. I have examined all the regulation works in this system without finding an instance of filling in between spurs, although some of these spurs have been in place for nearly sixty years. There has been no cutting of banks save where construction works have been unduly extended and, even here, the cutting has been just sufficient to pass the flow through a badly gorged channel. There is no instance of an undermined spur, owing to the proximity of rock bottom, although scour to the solid rock is the almost invariable rule at all spur heads.

These conditions make possible any degree of contraction consistent with a navigable slope. No further consideration has to be taken of the bottom than that it will probably scour until solid rock or boulders and cemented gravel are encountered. In the upper reaches, especially, the distance to such bottom is so slight as to make the scour negligible. The dams are built of rubble thrown in loosely. The growth of vegetation, especially willows, on these dams is very beneficial. The roots bind the stones together and preserve the dams. I do not recall an instance where any vegetation has grown on a spur in this river system. The sweep of the

water flowing over the spur seems to tear out all plants that sprout there. On the other hand, every longitudinal of any age has vegetation. For maintenance, the advantage is decidedly on the side of the longitudinal system.

The early dams were all timber cribs filled with stone. The timbers rotted away, and the stone, mostly rounded river stone, was largely washed away. The next type of dam tried was one of derrick stone alone. This type is open to several objections. It is hard to calk. Water creeping through undermines the gravel foundation, and the dam either settles or is broken. Drift carrying out a stone makes a considerable break, which widens rapidly from the force of the gorged water. The third type was of small stone. This proved better, but not entirely satisfactory. Any break widened with great rapidity, since the individual stones had not sufficient weight to offer any resistance, and the strength of the dam depended solely upon the thoroughness of the binding. The latest type is of the run of the quarry. Everything from a 2-yard derrick stone to a one-man stone is dumped in together. The whole is covered with spalls and quarry scrap, in addition to occasional skips of this material thrown in during construction. If a dredge is working near, it is well to cover the dam with dredged material also. The water packs in the finer dredged material until the dam is a thoroughly bonded mass. If drift makes a break, it does not take out any of the large stone, since they are too firmly bonded. The surface left in the break is as good a resistant as the original surface of the dam, causing the damage to extend very slowly and giving ample time for repairs.

In computing the effect of regulation works it is well-nigh impossible to make any correct allowance for leakage. If the leakage is less than allowed for, the slope will be greater and upset all calculations. On the other hand, if the leakage is greater than allowed for, the channel depth will be less than computed. I prefer to make no allowance for leakage and work to a slope greater than desired and a depth of from one-half to 1 foot greater than project depth. The result will fall somewhere between the two slopes and depths and will practically insure that the full project depth will be obtained throughout the channel. It is evident that the tighter the dam the more nearly will computed conditions be attained. The last-mentioned form of dam is the nearest to impervious of any. At the head of Half Moon Island a closing dam of this type held up water 4 feet with very little leakage. Regulation dams are always

tightest in the fall and most porous in the summer. This is due to the calking given by dead leaves caught in the dams. At Mathews Shoal, in the Hiwassee River, I observed a variation of three-tenths of a foot in upper pool level from this cause. In a short shoal this variation has a serious effect upon the velocity of flow. The best remedy I know for this is a few barge loads of gravel dumped on the upstream side of each dam. This calks as well as the leaves and will remain long after the regimen of the shoal has again become fixed.

Spurs do not become a full improvement until the accretions between them have reached the spur heads or nearly so. While these accretions are forming, the slope is necessarily constantly changing locally, which is a very undesirable condition. Until accretions are complete, the slope is divided into a series of very sharp falls at each spur head with quite flat pools between. Upstream of each fall there is a sharp current away from the spur. Downstream of each fall there is current toward the spur. The swift water and irregular currents give a pilot his hands full. This is an undesirable and unnecessary condition. If the accretions do not form, this state of affairs will continue indefinitely. Such is the case on the Tennessee system. Along a longitudinal dam the water flows with a current, so that a boat entering the channel will pass through naturally. The only differences in slope are caused by irregularities either in the bottom or in the width of the channel. The channel, however, must be wide to overcome a very serious objection. At the exact stage of submergence, and from that to about a foot higher, there is quite a sharp draw over a longitudinal dam. I have seen a large river steamer have to break its tow and take it out a piece at a time when caught against a dam in this manner. This draw ceases when the break of the dam is no longer visible, usually at about 3-foot submergence. The draw may be annoying at 75 feet from the dam and serious at 50 feet, in the extreme case. For this reason a channel along a longitudinal dam should be not less than 150 feet, unless this width at low water will not give the required depth with the full flow of the river.

With a channel which has a longitudinal dam on each side there is a draw in both directions away from the channel, and this, particularly in a bend, may be sufficient to block navigation at certain stages. In a channel of this kind I saw a boat and tow caught and held diagonally across the entire channel. The towboat was on one dam and the leading barge was on the opposite one. It required

half a day's hard work to get out of this trouble. A channel which has spurs from both banks is even worse. From the stage of submergence until boats can cross the dams night navigation is quite hazardous. Several times I have had to pass through such channels at night and always felt like joining the pilot in his imprecations against the man who built spurs from both banks. Pilots must have something to run by. In absence of better aids to navigation they run a bank if possible. This is really the only way it is safe to run on a dark night. If an improvement (?) is so arranged as to put the boat in midstream between the submerged heads of spurs, it imposes a burden on the pilot that is unnecessarily great. Unless a man has tried to find the break of a submerged spur on a dark night, he has no idea what a really difficult task it is. One shoal that had works of this class was a source of bitter complaint among the pilots. No boat dared to attempt it at night. Major Newcomer ordered the works on one bank removed and those on the other bank extended to give the same contraction. The work was done in high water, causing the works to be about a foot too high. Until the water fell enough to permit regulating the height of the new works properly, there was a terrific current through the shoal. In spite of this, boats used the channel at night, and the pilots were overjoyed at the change. I believe it is safe to say that a bank run must be provided if it be possible. Works on both sides of the channel should be a last resort, and spurs on both sides should never be used at all.

Maintenance of this class of works requires about the same kind of plant and about the same amount of plant as for construction. For this reason not very much of it is done. Works should therefore be so designed as to require the minimum of maintenance. The best built dams will deteriorate. In a series of spurs the loss from leakage is practically that of one spur. In a longitudinal system the leakage is along the entire dam, so the longer the dam the greater the leakage. I have observed, in works of this class, a loss of over a foot in channel depth from this cause.

While the banks of the Tennessee system are exceptionally firm, they are not adamant and will give way under the direct attack of water. For this reason all works connecting with the bank should incline about 15 degrees upstream for the 300 feet nearest the bank and should be well keyed into the bank. This throws the overfall away from the bank and prevents cutting around the bank end.

A longitudinal system can not be designed and built from theo-

retical designs and obtain the computed result. There are too many unknown factors to be taken into account. Every change in roughness, every irregularity, no matter how slight, produces its effect. These cause the value of C in the Chezy formula to change quite a bit in a very short distance. From a consideration of several hundred sections, I am of the opinion that the best that can be hoped for is to obtain a fair average value for this constant. The balance is too delicate for any available means of exact determination. In fact, C may change for the same cross section. Once installed, however, a longitudinal system must stay if the channel can be navigated at all, for the expense of changing such a system is enormous. A system of spurs, on the other hand, may be built out in stages until the desired result is attained.

A consideration of the merits of the two systems led to the belief that a combination of them would give the best results. Although more expensive than either alone, it would pay in getting and keeping the desired improvement.

My first experiment in this line was at Shields Dam, on the Tennessee, under the direction of Major Newcomer. An old State dam extended from the right bank, and a Federal dam of the longitudinal variety was at the proper distance from the left bank. The upper pool had to be raised and a channel cut. I extended the longitudinal downstream, to take up the added fall, and carried it around above the State dam to the right bank. The curve in the last extension was on a radius of 300 feet. Although built under the most adverse conditions of high water, the results were better than expected. The new dam was gravel; calked, and had no perceptible leakage; the current was smooth and regular, and the slope corresponded very nearly to that desired. A bank of gravel left by the dredge caused a slight engorgement at one point.

The second experiment was at Mathews Shoals, in the Hiwassee, under the direction of Major Newcomer. An existing longitudinal system was repaired and extended and tied to the shore with three cross dams spaced about twice the distance for spurs alone. The improvement was incomplete at the time of my departure. There remained to calk the dams with gravel, build a curved outlet at the foot of the improvement, and adjust the crests of the dams to the proper height. The observed effect was a swift, regular current through the shoal with a sharp draw toward the works at the foot. The curved dam, mentioned as not built, was to remedy this current. The leakage through the three cross dams was negligible.

The third experiment was at Upper Blackbird Shoal, on the Hiwassee River. The old works were completely removed and a channel cut along the right bank. The dredged material contained many boulders and much hard material. The bank cut was cast against the bank to form a protection. The cross dams, spaced double spur distance, were built out from the left bank until the upper pool was at the desired height. Their heads were then connected with a longitudinal. An unexpected result was obtained when the longitudinal was built—the upper pool rose approximately three-tenths of a foot. I account for this, that before the longitudinal was built, the flow between the spur heads was freer, and the water could pass with less head than when confined to a uniform narrow channel with increased bank friction. At this stage in the work the main river became low enough for work, and the plant was withdrawn. The observed effect was a sharp current toward the right bank at the head of the work and a sharp current and fall toward the left bank at the foot of the works. The cross dams were gravel calked as was the longitudinal. They showed no leakage, the water between the dams being quite dead. To complete the works, two more dams would be necessary; one dam at the head curving back on a radius of 300 feet from the longitudinal to make smooth the entering current; the other, a similar dam at the foot of the works to regulate the exit current and distribute the remaining fall.

The item of remaining fall is a hard one to determine before works are built. As an example: when the works at the head of Half Moon Island were extended and raised, it was hoped that the added fall would be distributed along the channel. This channel is 7 miles long from the head of Half Moon Island to the pool above Whites Creek Shoals. Very little of the fall was taken up in the 7 miles of channel, but practically the entire increased fall occurred at the foot. Special works at the foot will be necessary to take up and regulate this fall.

From a consideration of the above I am of the opinion that the regulation over a shoal should be carried out in the following manner: First, the computed dredging should be done. As this nears completion, spurs at double the proper distance should be led out in stages from one bank only, until the required difference in pool level is obtained. Then the heads of these spurs should be connected with a longitudinal. Next the dredging should be trimmed up and put into proper shape. The channel can now be used.

although the currents at the head and foot will be difficult, and there will probably be some extreme fall at the foot. Now leave the channel alone for a year to let the river settle to a more stable regimen, keeping meanwhile an occasional eye on the banks to stop any cutting that may arise. Then curve back a dam from the head of the longitudinal until the currents there are adjusted. If necessary, extend somewhat the longitudinal at the foot. Last, from the foot of the longitudinal curve back a dam to regulate the currents at the foot and to distribute the remaining fall.

This system has the smooth currents and slope of a longitudinal system. Its leakage is as small as in a spur system. It can be adjusted, during construction, with the same degree of nicety as a spur system. Any resultant error in fall can be taken up by reducing the height of the cross dams over a portion of their length until the upper pool level is adjusted. The cost as found from actual construction is about one-fourth more than the computed cost of a simple spur system. A bank run can practically always be provided. By adjustment of the crest elevation of the longitudinal the draw over it can be largely remedied.

A great deal has been written about the danger of lowering the upper pool level by dredging without the aid of contraction works. In the Tennessee system the dredged material can be used for sufficient contraction works. The dredged material is scattered over the bar and the flowing section kept constant. If the bar is a "hard" bar—that is, consisting of cemented gravel and boulders and similar material—the upper pool level may be actually raised by a concentration of the dredged material at the head of the bar. At Browns Bar, in the middle section of the Tennessee, I was able, with the material from three-fifths of the dredging, to raise the upper pool five-tenths of a foot to help out over Beards Reef. This is not true of "soft" bars consisting of gravel and sand. At Allens Bar, in the same section, I tried to get a few tenths more elevation in the upper pool to help out over Blue Rock Bar. The dredged material would stay on the shoal, but, at the slightest concentration, it would be distributed by the increased current. I was able to hold the pool level, but no more.

A feature in dredging, much appreciated by pilots, is to cast the outside cuts to the side. These form two walls that give a straight current through the channel. They stand several feet above low water, so that when they are submerged the pilots know that they

can run outside the channel. Willows planted on these walls are a great help in this same line.

To pilots a dredged channel crossing the current on a bar is an abomination. The pilots are right. With the swifter current over a bar, a dredged channel is hard to run if the current is across it. This is bad enough with packets, but with tows the trouble increases geometrically with the number of pieces in the tow. The pilot wants a bank run with the current on the bar and a crossing in the pool. After all, those archgrumblers, the pilots, must be given anything within reason. Upon them depends the success of the boat companies, and upon the success of the boat companies depends the use of our navigable streams and a large share of the return to the nation upon its investments in waterways.

# The Army School of the Line and Staff College

*BY*

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As a School of Military Engineering is to be established at Fort Leavenworth, Kans., in connection with the Army Service Schools at that place, it is believed that a description of the courses in the Army School of the Line and Staff College will be of interest to the Corps.

In the Army School of the Line there are four departments: Military Art, Engineering, Law, and Languages. In the Staff College there is one additional department: Care of Troops. The instructors in the Army Staff College are the same as in the School of the Line.

## Army School of the Line.

### *Department of Military Art.*

Of the 431 half days of the school year, 209 are allotted to this department, and are used as follows:

Troops in Campaign (19):
- 12 Conferences and discussion.*
- 5 Practical Problems.
- 1 Terrain Exercise.
- 14 Lectures.

Tactics—Part I (24):
- 10 Conferences and discussions.
- 7 Map Problems.
- 7 Terrain Exercises.

Hippology (3):
- 3 Demonstrations.
- 6 Lectures.

Weapons and Munitions of War (20):
- 18 Conferences.
- 1 Demonstration.
- 1 Examination.
- 2 Lectures.

Tactics—Part II (7):
- 2 Conferences.
- 5 Problems.
- 4 Lectures.

Tactics—Part III (34):
- 24 Conferences.
- 10 Map Problems.

* Conferences usually last from 9 to 10.30, or 1 to 2.30; practical work from 8 to 12 or 1 to 5; lectures from 11 to 12. Lectures are not counted as half days.

Tactics—Part IV (10):
10 Map Problems.
Tactics—Part V (25):
5 Conferences.
10 Map Problems.
10 Terrain Exercises.
Preparation of Problems (6):
3 Conferences.
3 Problems.
1 Lecture.
Conduct of War (11):
10 Conferences.
1 Examination.
Military History, Geography and Strategy (19):
16 Conferences.
3 Examinations.
34 Lectures.
Map Maneuvers (18).
Maneuvers with Troops (12).

Under the heading, Troops in Campaign, is grouped the instruction in Organization, Field Orders, Marches, Camps, Supply, and Military Hygiene.

Part I of Tactics deals with forces of a single arm from a patrol to a battalion, squadron, or battery. It includes patroling, advance guard, rear guard, outposts, convoys, infantry combat, cavalry combat, and the battery in action. In Part II the problems deal with commands of two arms, but not exceeding a total of one regiment. In Part III, Letters on Applied Tactics, by Griepenkerl, are studied and discussed, and original problems then given the class to solve. The forces used are generally the mixed brigade. Part IV is a general review of the course in Tactics. Part V consists in the study of a series of divisional strategical and tactical problems and their solution, after which the class is required to solve ten such problems, the United States Geological Survey maps being used. The terrain exercises constitute a further review of the course.

Out of a total of 1,000, the work in the Military Art Department counts 500, divided as follows: For practical work, 405; theoretical work, 95. "It is not to what one can memorize, but to what he can apply, that most value is given."

*Text-books.*

Minor Tactics (Studies prepared by the Department).
Field Service Regulations.
Drill Regulations—All three arms. (Reference.)
Orders—Swift.
Notes on Field Artillery—Spaulding.
The Rifle in War—Eames (in preparation).
Signal Corps Equipment in War (pamphlet).
Map Maneuvers—Sayre.
Letters on Applied Tactics—Griepenkerl. (Barth's translation.)
Conduct of War—Von der Goltz (Dickman's translation).
Conduct of War (English translation).
Tactical Decisions and Orders—Buddecke.

*Department of Engineering.*

The following table shows the division of the allotted time, with the weights assigned to each subject:

Military Topography (Surveying).

| | *Weight.* |
|---|---|
| Theoretical (23 half days): | |
| 21 Conferences | 00 |
| 6 Partial examinations | 30 |
| 1 Final examination | 20 |
| Practical (32 half days): | |
| Making surveys and plotting notes of same so as to construct by exact methods a contoured map of an assigned area | 75 |

Military Topography (Sketching).

| | |
|---|---|
| Theoretical conferences (4) | 00 |
| Practical military sketches (8) | 120 |

Field Fortification and Field Engineering.

| | |
|---|---|
| Theoretical (7 half days): | |
| 7 Conferences | 00 |
| Practical (23 half days): | |
| Field problems in Fortification and Engineering | 30 |
| Total for year (121 half days): | |
| Theoretical (50) | 275 |
| Practical (225) | 275 |

*The Course in Surveying—Conferences.*

This course consists of two parts, the theoretical and the practical.

The theoretical part includes fourteen conferences on advance and seven on review, six partial examinations, and the final examination.

The conferences are based on an assigned lesson. The instructor goes over the lesson, carefully explaining each point of the text, and developing its importance by graphical methods and additional matter.

The instructor, knowing the importance of each point in its relation to the whole subject, is able to clear up matters of great importance, about which the student might not at the time appreciate his lack of understanding, or think of sufficient importance to question.

The instructor having finished his review of the lesson, answers all questions, and asks such as may be necessary to still further develop the subject.

The lessons are arranged so that the subject of map reading is taken up first, on account of its importance in the problems of the Department of Military Art. On the first day a demonstration is

made on the sand table, and on the second day a study of ground forms and contour principles is made in the field, with the assistance of the staff class.

During the advance course, six partial examinations are held.

These are short examinations and may include any matter which has been studied to date.

*Practical Work.*

For the practical work in surveying, an area is selected with great variety in the ground forms, and all the work is concentrated on this area, the idea being to have the student become thoroughly familiar with every part of the actual ground, and then with the appearance of an accurate contoured map of the same area. This map is made by a combination of the survey methods which are most useful generally, but particularly with regard to their application in the making of hasty military maps. At this period of the instruction, the student uses exact instruments and methods, which later on he will use in much cruder form. The class is divided into parties of four, and the tasks are so assigned that each member of a party does one-fourth of the complete task in a different capacity.

The division of the entire survey is as follows: Each separate part of the work, in addition to the general instruction, being preceded by a half day of preliminary instruction, in which the regular instructors are assisted by the staff class, one member of this class being assigned to each survey party.

*Transit.*—By which the boundary of the designated area and certain features therein will be determined.

*Leveling.*—By which data for contouring a portion of the area will be obtained. Designated profiles and a system of cross sections will be run within the area.

*Plane Table.*—By which an assigned section of the area included in the transit boundary will be mapped by each officer.

*Contouring.*—By which the positions of certain contours on the ground will be determined and a survey made of a sufficient number of points of the determined contours to locate them on the map.

*Drafting.*—By which each officer will plot the notes of the surveys, transfer plane table work, and finish a complete contoured map of the entire area.

*The Course in Field Engineering Conferences.*

These conferences are of about two hours' duration and involve discussions based on pamphlets and lectures on such matter as is not contained in the regular manuals on:

*Bridges.*—The typical roadway bridges, their strength when in good condition and as effected by age, lack of repair, damage by natural causes, or

by an enemy. Methods of strengthening, permanently or temporarily, damaged bridges so as to make them efficient for carrying military loads. Methods of constructing military bridges and of destroying and disabling the same.

*Lifting and Handling Weights.*—Theory of tackles, selection of proper tackles and construction of proper field derricks, etc., with reference to particular work to be done.

*Fortification.*—Discussion of latest developments in field fortification, both as to trace and profile.

*Practical Work.*

This work consists of demonstrations and field problems in construction of trenches, revetments, obstacles, bridges; demolitions; use of tackles; tying knots; examination of bridges with a view to reporting on their strength, and of prescribing methods of strengthening those found too weak for military loads, selection of lines of fortification, etc.

*The Course in Sketching—Conferences.*

These conferences are of about two hours' duration each and involve discussions based on the text, developing by examples and graphical methods the most important details of the day's lesson.

*Practical Work.*

This course consists in map making by rapid methods suited to field conditions in time of war. The course comprises eight half-day problems for instruction, as follows:

Two position sketches.
Two outpost sketches.
Two road sketches, dismounted.
Two road sketches, mounted.

In these preliminary problems each two members of the School of the Line has the assistance of a member of the staff class.

After the preliminary course is finished, there are eight whole-day problems, which are marked. This set comprises:

Three position sketches.
One outpost sketch.
Four road sketches, mounted.

For the last road sketch a course of at least 20 miles is prescribed, and in marking the sketch the distance covered is considered, as well as the excellence of the completed sketch.

After this part of the course is finished, the School of the Line

combines with the staff class in executing a position sketch over a large area, and, if time is available, a combined road sketch. In these sketches the work assigned to the different sketchers is not of uniform difficulty and is not marked.

*Text-books.*

Topographical Surveying and Sketching.—Rees.
Individual and Combined Sketching—Cole and Stuart.
Applied Principles of Field Fortification for Line Officers.—Woodruff.
Notes on Cordage and Tackle.—Sherrill and Marshall.
The Examination and Repair of Simple Highway Bridges.—Sherrill.
Notes on Demolitions.—MacArthur.

*Department of Law.*

The following table shows the division of the 56 half days assigned this department, with the weights assigned each:

| | *Weight.* |
|---|---|
| Elements of Law—Theoretical (16 half days): | |
| 15 Conferences | 00 |
| 3 Partial examinations | 15 |
| 1 Final examination | 15 |
| Criminal Law—Theoretical (11 half days): | |
| 10 Conferences | 00 |
| 2 Partial examinations | 10 |
| 1 Final examination | 10 |
| Evidence—Theoretical (23 half days): | |
| 22 Conferences | 00 |
| 4 Partial examinations | 20 |
| 1 Final examination | 30 |
| Practical Exercises (6 half days): | |
| 6 Exercises | 25 |
| Totals: | |
| Theoretical | 100 |
| Practical | 25 |
| Year's Work | 125 |

*Text-books.*

Elements of Law.—Smith.
Criminal Law.—Clark.
Law of Evidence.—McKelvey.
Military Law and Precedent.—Winthrop (Reference).
Military Law.—Davis (Reference).

*Department of Languages.*

Of the 431 half days of the school year, 45 are assigned this

department. The following table shows the division of time, and the weight assigned each division:

| Spanish: | *Weight.* |
|---|---|
| Theoretical and Practical, 40 Conferences | 00 |
| Practical, 4 Oral Tests | 60 |
| Practical, 1 Written Examination | 40 |
| Total for year—Practical | 100 |

*Text-books.*

El Castellano Actual.—Roman y Salamero.
Spanish Grammar.—Ramsey.
Spanish Dictionary.—Appleton's (or one equally as good).
Exercises prepared in Department.

ARMY STAFF COLLEGE.

*Department of Military Art.*

Of the 431 half days of the school year, 181 are allotted this department, and are used as follows:

| | *Half Days.* |
|---|---|
| Conduct of War | 7 |
| Duties of the General Staff | 10 |
| Military History | 39 |
| Troop Leading | 18 |
| Preparation of Problems | 9 |
| Reviewing problems, directing war games and umpiring for School of the Line | 35 |
| Tactical and Strategical problems (6 conferences, 15 problems | 21 |
| Tactical Rides | 10 |
| Map Maneuvers | 8 |
| Preparation and discussion of original papers | 12 |
| Problems, Fortress Warfare | 12 |

*Text-books.*

Duties of the General Staff.—Von Schellendorf.
Studies in the Leading of Troops.—Von Verdy.
The Regimental War Game.—Immanuel. Krueger's translation (Reference).
Tactical Ride.—Von Verdy (Reference).

At the beginning of the course in September each member of the class is given a subject upon which he has to write a paper to be read before the class and by the class discussed. They make notes

and collect data as opportunity offers during the year, and toward spring nine half days are allowed them to complete their papers.

The subjects for last year's papers were:

1. The proper Training of an Infantry Company.
2. The proper Training of a Cavalry Troop.
3. Infantry Tactics in the Attack.
4. Infantry Tactics in the Defense.
5. Tactical Use of Modern Field Artillery.
6. Use of Heavy Guns with Field Armies.
7. Use of Machine Guns with Infantry.
8. Use of Machine Guns with Cavalry.
9. The French Invasion of Mexico.
10. Cavalry Raids, their value as shown by History.
11. Battle Losses.
12. The Organization of the Mexican Army.
13. Divisional Cavalry and Its Use.
14. Employment of Cavalry Divisions.
15. Tactical Lessons from the War in Manchuria.
16. Tactical Lessons from the War in South Africa.
17. The Transport Service with a Field Army.
18. Land Defense of our Sea Coast Forts.
19. Small Arms Ammunition Supply.
20. Field Artillery for our Army in War.
21. Independent Cavalry.
22. To what Extent can we use the Signal Corps in War?
23. Use of Mechanical Transport in War.
24. How Best to Instruct the Officers of our Army in Tactics.

The class was taken last year for a staff or historical ride from Manassas to Gettysburg.

The ride was announced to the class at the beginning of the school year and each member assigned the part he must discuss and the requirements made that careful study of all the campaigns involved was required of those to go. While five half days were allowed for preparation, it was but a small fraction of the time expended on it by the class. During the spring the staff class has, in other departments, much work that does not require preparation to be made at home. These evenings were what was counted on for preparation for this ride, and not amiss.

*Program for the Staff Ride.*

July 3. Wagons at train for baggage; horses, with lunch; Class to Bull Run field at the Henry house.

Papers on:

*First Bull Run, Gainesville, Groveton, Second Bull Run.*

Camp at Gainesville, 10 miles.

July 4. Move to Delaplane, 21 miles.

July 5. Move from Delaplane to Front Royal, 18 miles.
Papers on:
*Front Royal and retreat to Winchester.*

July 6. Wagons to Middletown, 9 miles. Class to Tom's Brook via Strasburg, and return via Strasburg to Middletown, 27 miles.
Papers on:
*Tom's Brook, Fisher's Hill.*

July 7. Move from Middletown to Winchester, 13 miles.
Papers on:
*Cedar Creek,* before leaving for Winchester. *Kernstown,* en route.

July 8. Remain all day at Winchester.
Papers on:
*Winchester, Opequon.*
Sketch of Jackson's campaign in the valley.
Sketch of Early's campaign in the valley.

July 9. Move to Harper's Ferry, via Charles Town, 28 miles.
Papers on:
*The Capture of Harper's Ferry, Events Leading to Antietam.*

July 10. Wagons to Sharpsburg, 12 miles. Class to Crampton's Gap, via Pleasant Valley, 9 miles; then to Turner's Gap, 7 miles; then to Sharpsburg for camp. Total for class, 24 miles.
Papers on:
*Crampton's Gap, Turner's Gap.*

July 11. Remain at Sharpsburg.
Papers on:
*Federal Right, Federal Left.*

July 12. Wagons direct to Hagerstown. Class via Williamsport.

July 13. Move to Fairfield, 20 miles.
Papers on:
*The Retreat from Gettysburg, Events Leading to Gettysburg.*

July 14. Move to Gettysburg, 7½ miles.
Papers on:
*The First Day's Fight, July 2d—Culp's Hill.*

July 15. At Gettysburg.
Papers on:
*The Battle of July 2d—The Federal Left, The Battle of July 3d—Left and Center, July 3d—Culp's Hill, Review of the Battle of Gettysburg.*

July 16. Allowance of a day for delays en route, or for seeing Gettysburg more thoroughly. In the latter case, the two last-named papers to be read on this date.

The above program was carried out.

The following problems were given out, and the solutions sub-

mitted were discussed by instructors and class. In most cases the discussions were very complete:

1. As Chief of Staff for General McClellan, draw up the order that should have been issued after obtaining the "lost order," September 13.

2. As Chief of Staff for General Lee, issue the order that should have been issued the night of September 14, at termination of Battle of South Mountain.

3. As Chief of Staff for General McClellan, write the order that should have been issued the evening of September 16.

4. Write the order for General Lee's withdrawal after the Battle of Antietam.

5. Take the situation of the troops as it existed the evening of June 30, 1863. As Chief of Staff for General Lee, submit a plan of action.

6. Same as above, except as Chief of Staff for General Meade, submit a plan of action for him.

*7a.* Was the position taken by General Sickles with his Corps, July 2, faulty? In other words, is his claim as to the position correct?

*7b.* With modern arms would the advanced position be better than the one ordered by General Meade?

The above problems were solved by class on the ground after a study of the same and hearing the papers and discussions relating to the battles in question, but without other preparation or warning.

### *Department of Engineering.*

The 108 half days allotted this department are used as follows:

| | *Half Days.* |
|---|---|
| Problem in Surveying | 25 |
| Acting as assistant instructors in the survey problems of the School of the Line | 5 |
| Field Problems in Fortification | 32 |
| Military Sketching (advanced course) | 21 |
| Acting as assistant instructors in the course in Sketching of the School of the Line | 11 |
| Map reproduction | 1 |
| Problem in Fortress Warfare | 11 |

In addition to the above, eight lectures are given the class on Fortification, including permanent and semi-permanent fortification, field fortifications of the Russo-Japanese War, the siege of Port Arthur, and seacoast defenses.

The problem in Surveying consists of an accurate instrumental survey of an assigned area, including triangulation control and an accurate measurement of a base line. The class is divided into parties of four, and each party is required to determine all the

details of the instruments to be used and the plans for laying out the work to the best advantage.

Each field problem in fortification requires three half days where the force involved is less than a brigade. The first half day is devoted to the general position to be fortified, including the division into sectors, force assigned each, position and strength of the reserve, position of the artillery, disposition of the cavalry, etc. The second half day is devoted to the details of the work, including the division into first line and supports, location and design of the infantry works, position and shelter for supports, communications and approaches, obstacles, clearing, and demolitions. The third half day is devoted to a discussion of the problem on the ground. On this day the works are traced on the ground with tape and stakes, and the various solutions of the problem are discussed. When the force involved is a brigade, five half days are devoted to the problem, two half days for discussion. For a division ten half days are devoted to the problem, four of them for discussion.

The course in Sketching includes rating horses, road sketches at the rate of 2, 3, 4, and 5 miles per hour; two combined road sketches covering five parallel roads and all cross roads for a 15-mile march, with combination and blue printing in the field the same day; three combined position sketches, one with the School of the Line, covering from 12 to 20 square miles, combined and blue printed the same day; and place sketching.

The Department of Engineering combines with the Department of Military Art in a problem in Fortress Warfare. This involves an application of many of the principles taught in both departments. Briefly, it consists of a map attack by a superior force on an inferior force strongly intrenched. The Department of Engineering supervises the fortification of the position and its attack by regular siege and such other features incidental to the preliminary transportation and march of the superior force as would naturally fall to the Engineer Corps.

*Text-books.*

Topographical Surveying and Sketching.—Rees.
Individual and Combined Sketching.—Cole and Stuart.
Applied Principles of Field Fortification for Line Officers.—Woodruff.

*Department of Law.*

The 62 half days allotted to this department are utilized as follows:

| | *Half Days.* |
|---|---|
| Constitutional Law | 22 |
| Military Government and the Laws of War | 11 |
| Martial Law | 11 |
| The Use of the Army in the Aid of Civil Power | 2 |
| Original Research | 16 |

*Text-books.*

Constitutional Law.—Black.
Military Government and Martial Law.—Birkhimer.
Cases on Martial Law.—Kreger.

*Department of Languages.*

The members of the staff class are allowed to take one of the following courses: German, elementary French, advanced French, advanced Spanish; 64 half days are allotted to the department.

*Text-books.*

German.

Geschichten vom Rhein.—Stern.
Glück Auf.—Müller and Wenckebach.
Conversational Lessons, complete, bound.—International Correspondence Schools.
Interpolated Sheets (from Department of Languages).

Elementary French.

French Verb.—Castaréde.
French Pronunciation.—De Pfeiffer.
Conversational Lessons, complete, bound.—International Correspondence Schools.
Contes et Légendes, 1re Partie.—Guerber.
Le Petit Soldat.—Kron.

Advanced French.

French Pronunciation.—De Pfeiffer.
French Verb.—Castaréde.
Le Petit Soldat—Kron.
Le Petit Parisien.—Kron.
Conversational Lessons, complete, bound.—International Correspondence Schools.

Advanced Spanish.

Spanish Verb.—Traub.
Introducción á Lengua Castellana.—Marion Des y Garennes.
El Castellano Actual.—Roman y Salamero.
Conversational Lessons, complete, bound.—International Correspondence Schools.

*Department of Care of Troops.*

The course in this department consists of sixteen lectures and conferences, covering the following subjects:

1. Selection of soldiers.
2. Clothing.
3. Shelter.
4. Food—Its preparation.
5. Water—Supply.
6. Exercise—Training—Work.
7. Sanitation in garrison.
8. Sanitation in camp and on the march.
9. Sanitation in battle.
10. Sanitation in battle.
11. Sewage disposal methods.
12-15. Prophylaxis against special communicable diseases.
16. Effects of heat and cold.

*The Mailing List.*

The secretary of the Service Schools keeps what is called a mailing list of officers of the Army, Marine Corps, and National Guard. Copies of all examinations, map problems with solutions, and maps, pamphlets, etc., are sent to these officers. At present there are about 2,000 names on this list, and it is rapidly increasing. Officers of the Corps of Engineers who wish to keep up with the latest developments in the Military Art should have their names put on this list, which can be done by writing to the secretary. Military and technical books can also be obtained through the secretary at practically wholesale prices.

# The Ralston Trestle for United States Bridge Equipage

*BY*

Capt. P. S. Bond
*Corps of Engineers*

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This trestle was designed by First Lieut. R. R. Ralston, Corps of Engineers, in an effort to produce a trestle having greater strength than the service Birago, without an undue increase of weight.

The following is extracted from a report on the Birago trestle made by Lieutenant Ralston and contains a description of the modifications which constitute the new form of trestle.

*Extract from Lieutenant Ralston's Report.*

In order to properly strengthen the trestle, it is necessary, first of all, to determine the heaviest loads that the bridge will be required to bear.

The heaviest load that a ponton bridge would be required to bear in a campaign would be that for a throng of disorganized men crowding upon it.

While the possibility that a bridge would be required to bear such a load is quite remote, yet it must be able to carry such with certainty and safety. Such a load might be as great as 80 pounds per square foot of road surface, and, considering the roadway 10 feet wide, would give a load of 800 pounds per foot of bridge, exclusive of weight of superstructure.

An investigation will show that while a bridge with floating supports will carry such a load, yet if a trestle were used such a load would result in stresses which exceed the ultimate strength of the present trestle.

To endeavor to construct a trestle to safely take such a load is out of the question, as it would be so heavy and bulky as to be almost unmanageable, since the total load on the trestle would be in the neighborhood of 18,000 pounds.

The next heaviest load liable to be placed on a ponton bridge in

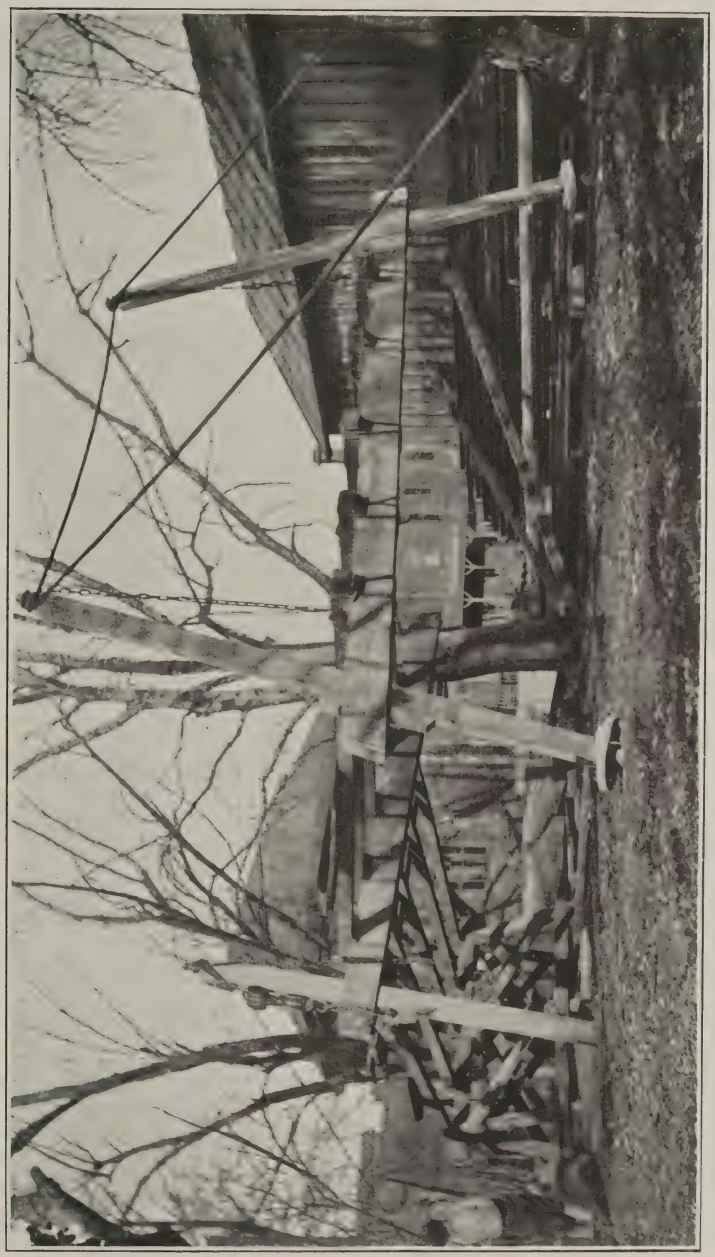

Fig. 1. Arrangement of tackle for adjusting cap of Ralston Trestle. Cap raised.

our service is the new siege material now being developed by the Ordnance Department.

This consists of a gun and carriage and limber, forming a wheel base of 14 by 5 feet and weighing 8,000 pounds, all told, the gun and its carriage weighing 6,000 pounds and the limber 2,000 pounds; the gun, which as a general rule is carried in the traveling position, may sometimes be taken on the march while in the firing position, which would cause concentrated loads of 6,000 pounds and 2,000 pounds, respectively, spaced 14 feet apart.

After the siege gun, the next heaviest load would probably be a loaded army wagon or a load of 6,000 pounds on a wheel base of 6 feet 6 inches by 5 feet.

The latter load is the one heavy load which the bridge will be required most often to carry.

The Birago trestle in the United States service consists of a built-up cap, two legs, and appliances for fixing the cap at the proper height on the legs.

These appliances consist of the chains and false legs.

The legs are inclined toward the center of the trestle at an angle of about 15 degrees for the following reasons:

1. To give lateral stiffness to the trestle.

2. To cause the legs to jam in the recesses provided for them so that the cap may be firmly fixed in place.

3. To give a sufficiently great distance between the bottoms of the legs, so that in case of the settling of one leg more than another the inclination of the cap will be minimized.

The action of the chain is as follows:

When the leg and cap are not securely jammed together, a weight on the cap will cause it to slip, which brings a tension on the chain. This pull on the chain has two components at the top of the leg, one at right angles to the leg toward the center of the trestle, which tends to jam cap and leg together, causing a transverse strain on the leg. The other component produces a compressive stress in that portion of the leg above the cap.

The trestle must be strengthened in the cap and in the legs. This may be done directly or indirectly.

Directly:

1. Cap may be made deeper or trussed, but it is believed that increasing the depth of the cap is preferable to trussing, since the

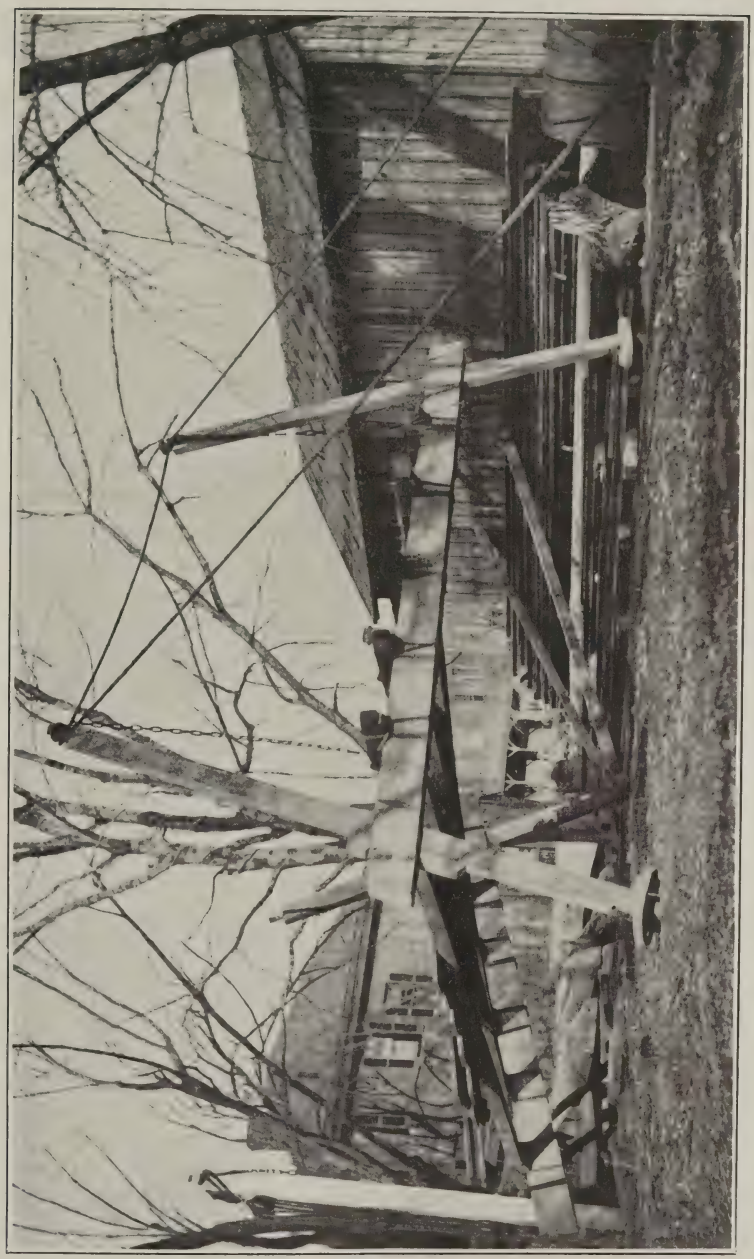

Fig. 2. Arrangement of tackle for adjusting cap of Ralston Trestle. Cap lowered.

latter depends on the tightness of bearing of the truss rod and will need constant attention.

2. Legs may be made wider.

Indirectly:

1. Legs may be given a less inclination and moved toward the center of trestle by an amount equal to that allowed by the decreased inclination, thereby decreasing the span and the cross strain on the legs.

2. This, however, will necessitate a different method of fastening cap and legs together, since 15 degrees is undoubtedly about the least angle at which they will jam.

3. The same applies in case the width of the legs were increased very materially.

Fig. 5 shows proposed strengthening of present trestle. To strengthen the trestle without such a large increase in size of caps and legs, it is proposed to strengthen it in part as above and in part indirectly by decrease of inclination of legs.

To do this, a different system of fastening must be used which is not dependent on the inclination of the legs, and the method shown in Fig. 6 is suggested, which explains itself.

The increase in depth of cap and width of leg is very much less in this form of trestle, and the increase of weight would be very small, since the cap can be shortened by about 3 feet.

This form of trestle would have the advantage of no cross strain on the leg due to the pull of the chain.

It has the disadvantage, however, of less lateral stiffness, and possibly some difficulty of adjustment, that can only be determined by actual experience.

A test trestle on Lieutenant Ralston's design was made at the engineer depot, Washington Barracks, D. C., and, by direction of the commandant, was tested by Company H, Second Battalion of Engineers. The legs and cap of the trestle were of white pine and the wedges of oak. The following is from the report of this test by the company commander, Captain Bond.

This trestle is very similar to the Birago, but, unlike most of the modifications of the latter which have been tested from time to time, it is simpler than its original instead of being more complicated. The design appears to be more scientific than that of the Birago. Its essential differences from the latter are as follows: The wedge

is set on the inside of the leg instead of the outside; the chains are attached to the wedges instead of to the cap; the wedges are set with the narrow part up and the broad part down; the legs are more nearly vertical than those of the Birago.

It was apparent to me at a glance, and before any tests had been made, that this trestle was superior to the old Birago. The wedge being set with its small end up, and being itself supported by the chain, the stability of the trestle cap is not dependent upon the slope of the legs, as in the Birago, and the legs may be made perfectly vertical if desired. The advantages of vertical legs are well known. They save weight. Lieutenant Ralston has given the legs of his trestle a slope of 10 degrees instead of 15 degrees, employed for the

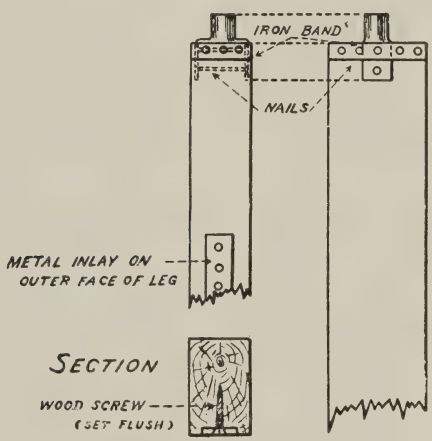


Fig. 3.

Birago. He expresses some doubt as to whether this angle will be sufficient to give lateral stability under all conditions, as when the bottom of one leg has to be placed considerably lower than that of the other. Some inclination of the legs for a military trestle is undoubtedly to be desired under certain conditions. The weight of the trestle, however, increases rapidly with the inclination of the legs, and there was no reason for so great an inclination as 15 degrees in the Birago, except that in this design the cap would not be stable with a less slope. The Ralston trestle, with vertical legs, would be serviceable in the general case, and the slope he has given (10 degrees) is, in my opinion, sufficient to insure lateral stability even under extraordinary conditions.

The weights of the Ralston trestle as compared with the service Birago are as follows:

| Trestle Parts. | Ralston. | Birago. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| Legs | 203 | 130 |
| Cap and wedges | 273 | 252 |
| Shoes | 22 | 22 |
| Chains | 60 | 34 |
| Total | 558 | 438 |

These figures, however, do not mean that the Birago trestle has any advantage over the Ralston in weight, the contrary being the case. On account of the less slope of legs and the shorter span of cap, it will be perfectly apparent that the Ralston trestle can be made lighter for the same strength than the service Birago. The trestle actually used in this test was far stronger than the service, as the results show.

The trestle was first assembled several times simultaneously with the service trestle. The average time of erection was slightly less than that of the service trestle.

The trestle was then placed between two bays of a bridge, and loaded to 19,500 pounds, in addition to the weight of the bridge, under which load the cap showed a deflection of about 1⅛ inches. This load was left upon the trestle for three days. As the load was applied the cap slipped down about three-fourths inch on each leg in settling to a firmer bearing. There was, however, no motion of the wedges relative to the legs, showing that there was no increase in the stress on the chain (and consequently on the upper part of the leg) due to the above-mentioned load, which was greater than the maximum requirements of service. This load was uniformly distributed upon each of the five balk and stressed them beyond the point of safety.

After the removal of the load, tests were made as to the ease of adjustment of the trestle, while in the bridge, with the flooring and balk in place. The simplest of expedients served to accomplish this adjustment. The method of rigging the tackle is plainly shown in Figs. 1 and 2. The tackle having been rigged as shown (one double and one single block), four men were placed on the ground at the foot of the leg (in some cases they might be in a boat). They

hauled up tight, after which the chain was released from the block or wedge on that side. The wedge was then knocked loose with a sledge hammer by a man on the bridge, when the four men were able to raise the cap until the tackle was chock-a-block and to lower it to the bottom of the leg with perfect ease. This was done several times on each leg, and not the slightest difficulty was experienced. In one case, having made very short slings on the leg and cap, I raised the latter almost to the top of the leg. (See Figs. 1 and 2.) This maneuver can be performed from the deck of the bridge as well as from the ground. It will be noted that this maneuver was readily executed after the wedges had been jammed tight by a load

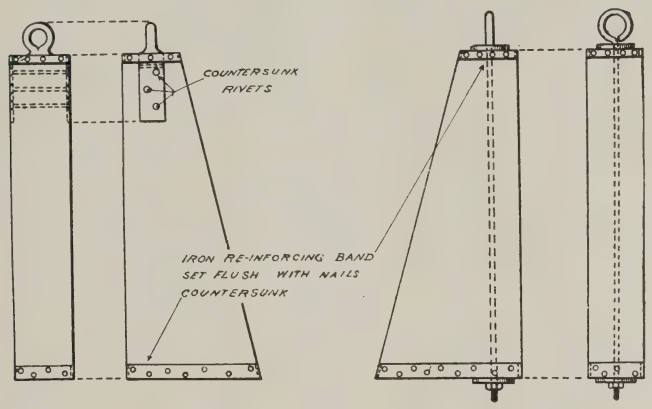


Fig. 4.

far greater than the trestle would usually be called upon to bear in service.

The tests thus far described appear to be complete and conclusive, as I noted that the great load referred to produced no injurious effect upon the trestle, except as stated hereinafter. The mere question of the breaking load has no particular bearing upon the excellence of the design. I made the breaking test, however, in order to learn, first, whether the legs or the cap would fail, and, second, what would be the ultimate strength of the weaker of the two. The purpose of this was to learn if economy of weight could be effected. The cap was set at a position slightly above the middle of the legs, its top about 7 feet above the ground. It was my judgment that it would seldom be necessary to place it higher than this, since in deeper water a boat could be used. However, a trestle being lighter than a boat, it would frequently be possible to greatly

increase the length of bridge for the same weight by using trestles into as deep water as possible. The height of 7 feet was selected in this case, and the legs showed no signs of weakness at the time that the cap ruptured. The cap was uniformly loaded to 24,500 pounds, at which point it suddenly ruptured a little to one side of the middle. The center deflection just before rupture was 2½ inches.

I believe a few slight modifications in certain details are desirable. The outer edges of the legs were somewhat crushed and indented by the pressure of the end pieces of the cap. A strip of iron inlaid over the center half of the outer face of the leg would increase its durability. With a vertical leg there would be no such crushing tendency at this place. The eyebolt which passes through the wedge should be more firmly secured. It should have a shoulder at the upper end and a heavy wrought washer at each end; this for the reason that in making adjustments of the trestle it is necessary to dislodge the wedge by driving on the top of it with a sledge or maul, and it is impossible to avoid hitting the eye of the bolt in so doing. The yoke in the chain by which the pull is distributed to the two sides of the trestle leg is a good feature. I am of the opinion, however, that the pin at the top should be of metal and strapped onto the square end of the leg. (See Fig. 3.) The spike at the foot of the leg might advantageously be made in the same way. This would reduce the work of construction to a minimum; if a leg should be broken, it would only be necessary to square up a new timber and attach to it the irons of the old leg. The wedge itself should be strengthened by a collar of iron around each end of it to prevent splitting. To avoid interference in operation, these collars should be set flush with the wood or slightly countersunk. (See Fig. 4.) Other slight modifications of details may be suggested by experience.

I observed very carefully the motion of the wedge relatively to the leg of the trestle as the load was applied. The greatest motion that I detected was less than one-eighth of an inch. It is apparent, then, that the strain on the supporting chain is very slight, and hence the chain appears to be unnecessarily heavy. In fact, it could be dispensed with altogether, as a light balk lashing would serve to hold the wedge in place while the cap was settling to a firm bearing on the leg. The weight of the trestle could thus be reduced 60 pounds. It would then be 60 pounds, or 14 per cent, heavier than the Birago, with which it was compared, although having a breaking load more than twice as great. (This Birago trestle has been loaded

up to 8,000 pounds, at which point rupture appeared to be imminent. The Ralston ruptured at 24,500 pounds.)

Although not primarily designed for ease of adjustment, the Ralston appears to be all that could be desired in this respect. There is nothing automatic about its adjustment, and there are no theoretically ingenious devices. But it is simple and certain. It requires about five men to make the adjustment with a single block and a double block. With a chain block of small power two men could readily make the adjustment. Certain of the other proposed types of trestle can at times be adjusted by one man, but at other times the bridge must be taken down and set up over again. The Ralston can always be adjusted in place. In the tests made, no trouble was encountered in removing and replacing the wedges, whereas the

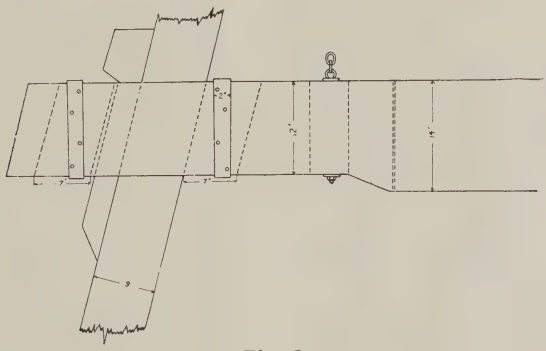

Fig. 5.

wedges of the Birago are frequently broken in this process. No overhead rigging for the purpose of giving an oblique pull on the cap is necessary, although the service Birago can also be adjusted without such rigging, but not so readily, on account of the greater slope of the legs and the greater difficulty of removing and replacing the wedges.

It will be observed that the experimental trestle proved to be even stronger than Lieutenant Ralston anticipated. Thus he says that it is impracticable to build a trestle to carry a load of 18,000 pounds on account of the great weight. The trestle constructed according to his design sustained a load of 19,500 pounds for three days without any signs of weakness. There are a number of reasons for the great strength developed by this experimental trestle. In the first place, it has been assumed in making calculations for trestles of this type that the span of the cap is the distance between the feet of the trestle; that is to say, if, without moving the cap

and the load upon it, we should lower the ground under the trestle and piece out the legs to reach the ground in its new position, we assume that the stresses on the cap are thereby increased. This is manifestly an error (although on the side of safety). The stresses on the cap depend upon the size of the cap and the inclination of the legs. The length of the legs has nothing to do with it, and there is no more strain on the cap when it is placed at the top of the legs than when it is placed at the bottom. The effect of the inclination of the legs is to produce an end thrust in the cap, which increases the compression in the compression flange of the cap and diminishes the tension in the tension flange. The amount of this compression is $\frac{1}{2}W \tan a$, where $\frac{1}{2}W$ is the reaction at the leg and

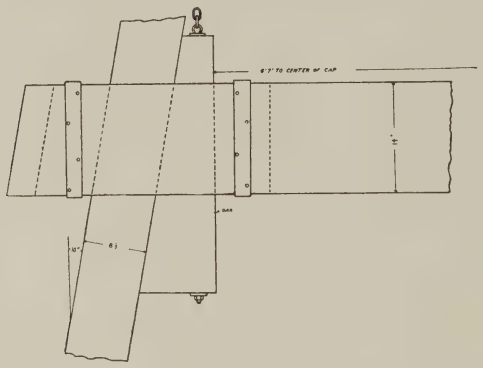

Fig. 6.

$a$ is the angle of inclination of the leg. The amount of this thrust is slight, being only 2,000 pounds when the load on the cap is 24,000 pounds, and being more or less well distributed over the entire cross section of the cap (56 inches). The cap of this trestle is also assumed as a beam resting on two points of support. Under the action of a heavy load the ends of the cap wedge tightly against the legs, and the cap approaches the condition of a beam securely fixed at both ends. Just how closely it approaches this condition, and just how near the usually accepted formulas for this condition approach the truth, I am not prepared to say. The breaking load of the cap as actually constructed may be taken as an indication of what may be expected of others similarly constructed, but of different dimensions.

I am of the opinion that this trestle fulfills the requirements of a military portable trestle better than any other that has as yet been tested in the United States service.

# MODES OF GAUGING THE FLOW OF WATER*

*BY*

HENRY L. ABBOT
*Professor of Hydraulic Engineering*
*Late Colonel, Corps of Engineers*

Any variation in the head acting upon a water surface determines a tendency to motion, and if a channel be open, a flow. The volume transported in a given time can be computed when the area of cross section and the mean velocity are known, and it is these two elements, together with the effective head, that are specially involved in practical gauging operations. Measurement of flow in pipes, over weirs, in natural channels, and of underground flow will be considered this evening.

## FLOW IN PIPES

The control of systems of water supply for cities, or for rented water power, demands elaborate measurements to determine the flow through pipes and thus to check waste. The Bernouilli and Chezy fundamental formulas ($V = \sqrt{2gh}$, and $V = \sqrt{rs}$), with modifications to suit special cases, permit the use of a variety of meters for moderate volumes; but an invention of Clemens Herschel, named by him the Venturi meter in honor of the Italian physicist who in the last decade of the eighteenth century first investigated experimentally the flow of water through diverging ajutages, enables the flow through pipes even of the largest sizes used for city mains to be registered continuously and automatically. Venturi discovered that when a uniform volume of water flows through a pipe of diminishing or increasing cross section the pressure exerted on its surface varies inversely with the velocity of flow. From this principle and the Bernouilli theorem, $V^2 = 2gP$, it results that when in an ordinary pipe line is inserted a truncated reducing cone, coupled by a short throat piece to a similar but longer expanding cone, and by piezometric tubes or other devices the difference in pressure at the throat piece and at the cone inlet is measured, the mean velocity at the throat piece, and

* Lecture delivered before engineer students in the post-graduate courses, George Washington University, March 31, 1909.

hence the volume passing, may be computed. The volume is given by the formula

$$Q = k \frac{Aa}{\sqrt{A^2 - a^2}} \sqrt{2g(P-p)}$$

in which A and $a$ denote inlet and throat areas of cross section, P and $p$ denote inlet and throat pressure, Q denotes the discharge, and $k$ is an instrumental constant which, except for abnormally small discharges, should differ but little from unity. Thus the only quantities to be measured at a gauging station are P and $p$, or, rather, the difference between them. An ingenious instrument, supplied with the meter, records continuously and if desired transmits to the engineer office the results of the measurement.

Such is the Venturi meter, now largely used both in this country and abroad. A good example of its utility occurred at the Columbian Exposition at Chicago in 1893. A 36-inch meter was installed to measure the water consumed on the grounds, although the Company supplying it had set apart a pump which by the number of strokes made the volume known. When the bill was presented, it was found that nearly double the volume recorded by the Venturi meter was charged, or eleven million instead of seven million gallons daily. Investigation proved that by some blunder of an agent an old box gate conducting to a branch pipe had been opened, without the knowledge of the Company, and the exposition dividend was thus largely increased by the use of this newly invented meter, which had been introduced into practical use only three years before. The instrument is now used largely for gauging the flow in the water-supply system of Washington City, and is well suited for use in regulating the flow at irrigation works.

## WEIR GAUGINGS

In water-power installations it is often desirable to know with accuracy the volume of water escaping over the dam; and, knowing the dimensions of cross section and the head in approaching the crest, this may be computed by formulas, more or less trustworthy, according to the details of the weir construction. Where a weir is specially prepared for the purpose, it should fulfill the following conditions, as laid down by Bazin who has conducted numerous experiments upon this kind of flow and who is a recognized authority; they eliminate many troublesome corrections:

(1) The sill of the weir should be made as high as possible above the bed of the stream, to avoid interference by eddies below.

(2) Unless the weir crest is long compared with the head, the lateral

contraction should be suppressed by making the channel approaching the weir with vertical sides, and of the same width as the weir.

(3) The sill of the weir must be made sharp-crested.

(4) Free access of air to the sides and under the nappe of water must be insured.

Under these conditions the weir formula takes the form:

$$Q = CLh\sqrt{2gh},$$

in which Q denotes the discharge, L the length of the weir crest, $h$ the head measured from the still water surface above the weir, and C is a coefficient for which Francis deduced experimentally the value 0.415, and which Bazin represents by the formula $C = 0.405 + \frac{0.00984}{h}$. The head is to be measured accurately by a hook gauge operated in a box containing water whose surface level is regulated by a pipe extended to still water above the weir; the zero of the gauge is placed at the level of the weir crest transferred to the box by a spirit level. By slightly raising and lowering the hook, the desired height, that at which the point just touches the water, can be noted with great precision. If there be a velocity V of approach to the weir, the head thus observed must be increased by about 1.5 times the quantity $\frac{V^2}{2g}$.

The practical difficulty in weir gaugings results from the fact that it is seldom that the above conditions demanded for extreme accuracy are encountered in practice, because they do not conform to ordinary dam construction, and recourse must be had to formulas more or less doubtful to correct for differences in form of crest. A good summary of these formulas, with an account of the studies upon which they are based, will be found in Water Supply and Irrigation Paper No. 200, by Robert E. Horton, published by the United States Geological Survey in 1907.

## GAUGING OF RIVERS

Before undertaking any important work of river improvement it is desirable and often necessary to know its maximum, its minimum, and its mean discharge. When the requisite data have not already been collected, this involves much time, for the annual and secular variations in rainfall are reflected in stream flow, and extremes become known only after the lapse of years. Long-continued rainfall records at sites suited to determine the average precipitation throughout the drainage basin are extremely useful. Information as to the maximum heights of water level are relatively easy to obtain, but only vague statements can generally be had as

to minimum level. Long and continuous records of water level, preferably by a self-registering instrument, are to be desired. They should always be checked occasionally by readings upon a permanent graduated rod, whose zero is referred to one or more bench marks established to preserve the best available datum level, such for example as mean tide. Such bench marks above ground, often marks on buildings or cuts on trees, are liable to destruction; the best form is a buried metallic plate having a platinum reference point, whose locality is marked by angles recorded from points easily identified. A bench mark of this kind, established by the State engineer long years before on Bayou La Fourche, Louisiana, once served to correct an important misapprehension as to the effect of levees, subsequently built, upon the level of the bed of that stream.

A discharge measurement involves the determination of two quantities to be made at a site where the flow follows a straight channel of as uniform cross as can be found in the vicinity, the area of cross section, and the mean velocity of flow. Both section and velocity are subject to continual variation. What is called the "mean velocity" is the quotient of the discharge by the total area of cross section, and is a quantity which can not be directly measured; the true discharge can only be found by taking the sum of the products of partial areas by the corresponding local velocities. The soundings to determine the cross section should not be restricted to a single plane, but should cover a sufficient length of channel to eliminate variations tending to develop gains or losses of living force; and if, as is often done with a meter, the computations are based on a single plane it should be so located as not to differ sensibly in area from the general mean.

The resistances to flow arise not only from friction at the wetted perimeter, but also from wind forces acting at the surface parallel to the direction of motion, being positive for upstream and negative for downstream winds. The discharge remaining constant, this surface resistance largely determines the depth of the fillet moving with the maximum velocity, which depth $d_1$ is indicated by the formula $d_1 = (0.317 + 0.06\ F)\ D$, in which D denotes the depth of the stream at the point considered, and F the wind force acting up or down stream parallel to the current; its value ranging from 0 to 10 between a calm and a hurricane, and its essential sign being positive or negative according to the direction of motion. The entire vertical curve denoting the change of velocity from surface to bottom when flowing uniformly is represented by a parabola of which the axis is horizontal and parallel to the current, and situated at varying

depths, according to the effective wind force. The form of the curve is indicated by the following formula:

$$V = V_{d'} - \sqrt{bv}\left(\frac{d-d'}{D}\right)^2$$

in which V is the velocity at the depth $d$, $V_{d'}$ is the maximum velocity, $v$ is the mean velocity of the stream, and $b$ is sensibly 0.19 for deep rivers, but increases rapidly in small streams, its local value being shown by the expression $\frac{1.69}{\sqrt{D}+1.5}$.

This experimental analysis of the laws governing the normal change of velocity from surface to bottom in a vertical plane parallel to the flow has an important bearing upon the practical gauging of rivers. It is easy to show mathematically from the properties of this curve that the velocity at mid-depth bears a constant ratio to the mean of the entire curve, no matter what be the depth of the axis; this ratio at any other depth is subject to considerable variation due to winds, and is not readily determined.

This parabolic law defining the effect of cohesion upon the transmission of resistances through the fluid was discovered experimentally by the Mississippi Survey, directed by General Humphreys, from an analysis of 516 well-determined vertical curves, including both high and low stages, measured on the river itself at four different localities, confirmed by similar measurements upon bayous Plaquemine and La Fourche, and confirmed by Boileau's hydraulic experiments in a wooden canal at Metz in 1850 and by some special measurements made later for the purpose on a canal feeder near Washington. Care had always been taken to record the direction and force of the wind, which seems to have been generally neglected by other observers; and from the study of this element it resulted that, as already stated, velocity should be measured at mid-depth to obtain the true mean of the entire vertical curve. Since that date a six-tenth depth has been generally adopted by engineers to attain this end, but the reason for the preference is not apparent. The data indicate that the velocity at mid-depth ranges only from 0.96 to 0.98 of the mean, as the latter increases from 1 foot to 8 feet per second, and is independent of the wind; but, on the other hand, that the velocity at six-tenth depth, although differing but little from the mean when a moderate wind is blowing upstream, is less in calms and considerably less in downstream winds than the desired mean. The mid-depth would seem to be preferable, although the six-tenth depth probably would not differ very materially in its indicated velocity. It remains to consider how velocity itself is measured. At experimental stations a great variety of instruments are

available for this purpose, but for flow in natural channels only two methods are now in general use—by meters and by floats. The merits and defects of each will be considered.

## METERS

Various patterns of meter have successively been put on the market—Saxton's, Wurdeman's, Gurley's, Price's, etc. They all depend on counting the revolutions of an axis caused by the action of the current upon vanes like those of a windmill, the number of revolutions being registered either mechanically or electrically by suitable apparatus. By suitable weights they may be sunk to any desired depth from a bridge, or from a boat, or from a car carried by a cable stretched across the stream, or, in brooks, from the hands of a man wading across and carrying the meter. For small streams these instruments are largely used, but on great rivers their delicacy renders them more or less unfit. The Saxton pattern was tested and found unsuitable near New Orleans; and, although a later pattern was used under the Mississippi River Commission on the upper river, the check afforded by comparing the relative discharge at different localities, taking into account the recorded variation of level at intermediate points, gave figures far less satisfactory than when floats had been used. For use, especially on considerable streams, there are three defects inherent to meters that should be remembered: (1) Everything depends on the constancy of the coefficient for translating revolutions of the axis into velocity of flow. This coefficient is usually found by moving the meter at a known velocity through water at rest, and it is assumed that the value is equally applicable to the case when the meter is held at rest in water in motion. This may or may not be true, depending on the influence of other bodies in the vicinity upon the flow in the two cases; furthermore, any change in the instrument caused by deterioration, or by shock or entanglement with light floating bodies, or in readjustment, may radically change the numerical value of the coefficient without the knowledge of the operator. (2) The meter records the velocity in the direction in which its axis is pointed, and in a river there are often changes in direction due to local obstructions. In large rivers this is often manifest to the eye by boils, whirls, and eddy currents. In such cases the velocity recorded by the instrument may not be that perpendicular to the plane of cross section which is needed to truly indicate the volume of discharge. Errors from this cause are especially to be feared in measuring the tidal flow over bars, where, owing to the meeting of fresh and salt water, the flow at bottom may be actually upstream when at the surface it is in the opposite direction. (3) For velocities less than about 0.5 feet per second the

records are recognized by good authorities as not trustworthy. In fine, it may be said that while meters are very convenient, especially on small streams, it is quite possible that important errors may result from their use unless the agent is well instructed and careful.

## FLOATS

These are of different kinds, varying with the character of the stream. The velocity being determined by the quotient of the distance passed over by the time of transit, the floats must be released far enough upstream to acquire full velocity before reaching the upper section; and the cross sections must be perpendicular to the direction of flow, or the length of path actually traversed between them, taken from the plat, must be used in the computation. In canals of uniform cross section, such as the head race at a water-power station, rod floats nearly equal in length to the depth and loaded at the bottom so as to float vertically serve in a manner to integrate the entire vertical curve, except for a short space near the bottom. By careful experiments Francis succeeded in deducing a formula for correcting this deficiency; denoting by D the depth of water, by $d$ the immersion of the float, by Q the true discharge, and by $q$ the uncorrected value indicated by the computation, his final revised formula is the following:

$$Q = q\left(1.012 - 0.116\sqrt{\frac{D-d}{D}}\right).$$

Provided special precautions are taken to release the rod float only at the instant when it assumes a vertical position, at a point well above the velocity base, this method is excellent for canal gauging; but for natural channels where the depth varies at different points of the section other methods are preferable.

Light surface floats are convenient to manipulate, but the ratio between their indications and the mean of the entire vertical curve is subject to so great variations, from the varying resistance opposed by winds acting upon the water surface, that other depths are to be preferred when extreme accuracy is an object. Under any circumstances floats should be light and should have sufficient depth to get a good hold on the water; bottles carrying small flags and ballasted so as to show but little of the neck above the surface serve well for the purpose. Heavy bodies are acted upon by a tendency to slide down hill, although the slope of the water surface is so gentle that this is generally forgotten. On the Mississippi a loaded coal barge will always pass by drift logs, and the latter will pass by light floating bodies, and yet the slope of the water surface is only about 6 inches to the mile. Part of this acceleration is doubtless due to difference

in depth of submergence, but this alone is hardly sufficient to explain the fact.

Double floats, although more difficult to operate, are superior in precision to any other kind, as they can be adjusted to any depth, and permit successive measurements at all depths, or the selection of the best depth to secure a uniform ratio to the mean velocity of the entire vertical curve, which, as already stated, is at or near mid-depth where the effect of variable wind force is eliminated. A double float should consist of a large lower body connected by a fine line to a light surface body carrying a small flag; the preferable pattern will depend on the size of the stream. If that be small, the lower float may well consist of two strips of tin bent at right angles and soldered together at the bend so as to form four radial arms of equal length and surface; this is connected by a wire or fine cord to two bits of cork, one at the top of the lower body and the other at water surface with a view to placing the largest possible area at the desired depth. For large rivers this construction is too delicate to be readily manipulated, and a keg without top or bottom, ballasted to hang vertically and connected to a small surface float by a fine cord, gives good results.

The distance from the banks may be estimated in small streams from a graduated cord suspended above the water surface; in large rivers pocket sextants or theodolites are used to locate the points of crossing each of two planes at right angles to the banks, between which the velocity is timed by a stop watch. This method permits correction to be made in case any float should be diverted from its true course by cross currents; and a plat permits the entire work to be studied. The site should always be chosen in a straight reach of as uniform a cross section as possible, whatever be the method adopted for measuring the velocity.

The labor of computation may be greatly reduced by the use of a planimeter. Draw upon the platted cross section a series of equally distant verticals, and plat the corresponding depths in feet one after the other on a single horizontal line on section paper; at each successive terminal point plat, as an ordinate, the corresponding velocity in feet per second, taken from the velocity plat by averaging the adjacent measurements and interpolating if gaps exist; connect the ends of the ordinates, including the initial point, by right lines; the area of the figure thus formed, measured by the planimeter in scale units, will be the desired discharge in cubic feet per second.

To find the mean velocity graphically, the following method may be used: Upon the water line of a plat showing the dimensions in feet of the vertical cross section lay down the points where the floats passed; at each point plat as an ordinate the velocity in feet per second there noted; con-

nect the ends of these ordinates by right lines; the area of the figure thus formed, extended to include the banks, is next measured by the planimeter; the quotient of this area by the width of the stream in feet is the desired mean velocity. If upon inspecting the plat it be seen that one or more gaps between floats occur at places where the depth varies considerably, ordinates may be interpolated, based on what appears to be the general law of change between banks as indicated by the floats observed. Such corrections correspond to those indicated above in the method of finding the discharge graphically.

## RATING TABLES

The object being to learn the volume carried periodically, not momentarily, by the stream, the next point to consider is how the series of gaugings should be combined to generalize the data.

At any stand of the river the local slope governs the discharge, and as the former is subject to constant variation the latter varies in like manner. A sudden freshet in an upper tributary produces a wave which passes downstream, causing at the gauging station an increased slope when approaching, a diminished slope when passing, and a still smaller slope when the combined effects of a falling river above and a rising river below are felt. These changes in volume at a given water level may be very great. On the Mississippi, even below Red River where such changes are much less than below the Ohio, the difference in volume carried by a rising and falling river often amounts to 10 per cent, while at Columbus, 20 miles below the Ohio, where the range is about 38 feet, an extreme difference of 30 per cent in volume has been noted at a level about 10 feet below high water; this difference occurred between the volume carried by the river in December, 1857, when rising at a rate of a foot per day with a velocity of about 8 feet per second, and in July, 1858, when falling at a rate of about 2 feet per day with a velocity of about 5 feet per second. The diminution of volume was 397,000 feet per second out of a flow of 1,138,000 feet per second. Such variations in volume at the same absolute water stage, and the fact that gaugings must be restricted to the hours of daylight, make it evident, especially for streams of torrential regimen, that for an accurate estimation of continuous discharge resort must be had to continuous records of water level interpreted by carefully studied rating tables based on numerous gaugings, and that it is not sufficient that such tables be formed, as is often done, by drawing on the plat a hand line conforming as nearly as may be to the general direction of a few measured discharges. For dates when the stream is subject only to gradual changes of level such a method may be permissible; but when the flood volumes

differ or are not of record, in order to safely predict the larger values the general law of the entire curve should be studied algebraically, either by the method of least squares or by equations of conditions to compel the curve to pass through as many well-determined points as its constants will permit. For streams subject to rapid rises resort must be had to special rating tables based on the gaugings at such dates, with an effort to follow the mid-line intermediate between volumes indicated for the rising and falling river; such a curve will indicate correctly the average volume during the freshet, although not that passing at any particular stand. Here, too, comes in a marked difference of regimen in different streams. Some usually retain an elevation differing but little, with sudden freshets of short duration; others are subject to considerable gradual oscillations with similar rapid rises and falls superposed. Naturally the latter call for more care and technical skill in analysis.

Thus far the case of a tolerably uniform cross section has been considered. Where this element is subject to large variations as the water rises, both area and velocity should be treated separately, as above indicated, and the rating table be formed by multiplying corresponding values. This method gives due weight to both causes of variation.

These considerations make it clear that rating tables demand serious study to secure satisfactory results. The object should be not to reproduce the exact figures given by a few measurements, but to follow the mean line resulting from many measurements taken when rising and falling, with a view to represent the most probable discharge during long, continuous periods. For torrential streams separate rating curves should be prepared, one for use when the river is slowly changing its stage and the other for use in freshets. For great rivers, where such rises are liable to occur at widely different stands, several freshet tables may be desirable corresponding to the height above low water at which the rises occur, but for torrential streams this is rarely necessary.

Any important local change in cross section, from caving or otherwise, of course entails a revision of the rating table, but not necessarily its rejection. A study of a few old and new gaugings made under like conditions before and after the change may indicate a correction ratio. The law of average slope variation between high and low water as registered by numerous data under the old conditions is not likely to be materially modified by any ordinary local change in cross section.

## UNDERGROUND FLOW

The movement of water in seeking a lower level is not confined to the beds of rivers; where the soil is pervious underground flow may be con-

siderable, and measurements to determine the direction and velocity may be required. Whether any such flow exists may be learned by an elaborate study of the ratio between downfall and drainage, in connection with rainfall records and the measured flow of the stream draining the basin under consideration. The variation in this ratio as rainy and dry months succeed each other will throw light upon the existence of an underground flow toward the main drainage lines of the basin.

But a system of direct measurement has been sometimes employed, both in this country and in Europe, in connection with the probable supply and the purity of drinking water in wells. It was first employed in 1882 for tracing the origin of typhoid fever germs near Paris and consisted in introducing into the underground current some foreign material, which could easily be recognized, and tracing its course by samples from wells, borings, or springs along its probable course. The material chosen when dissolved in water should be easily recognized by color, by chemical tests, or by microscopic examination. Many varieties, including common salt, have been tried, and fluorescein, a coal-tar product, seems to give the best results for tracing a flow through well-defined subterranean channels. Velocities ranging from 3 to 16 feet per minute have thus been measured in France over courses up to about 18 miles in length. Hourly samples are collected for tests. Important results from a sanitary point of view have been reached in connection with the water supply of Paris, and the method has recently been applied in southern Georgia in a limestone district.

For the more general purpose of investigating the direction and velocity of underground flow the electrical method of Slichter possesses marked merits. It consists of sinking by water jet test wells of driven or other pipe having diameters suitable to the depth and the nature of the soil; for 40 feet a 2-inch pipe usually suffices. The probable general direction of the flow may be inferred from the local topography, or by a survey of the vicinity determining the relative level of the water surface in springs, wells, etc., which will make known, approximately, the slope of the water table. The upstream well is located at the supposed highest point in the vicinity, and on the lower side are placed three or four downstream wells, distant some 4 or 6 or 8 feet from it, and lying on the circumference of a circle of which it is the center. They are spaced some 2 or 3 feet apart and, covering a fan-shaped area, serve to determine with precision the direction of the underground flow. All the wells have perforated screen points to permit the free flow of water. The distances suggested between them are chosen with a view to economize time, so far as practicable verticality of boring will permit. The electrical apparatus may be either direct reading

or self-recording; it consists of a battery, a galvanometer, and an electrode. (In case self-recording be preferred, the galvanometer is replaced by a recording ammeter and commutator clock.) The electrode consists of a nickeled brass rod, three-eighths of an inch by 4 feet, insulated from the casing by wooden spools; it communicates with the surface by means of a rubber-covered wire. The circuit starting from the casing of each downstream well passes through its battery and galvanometer to the electrode submerged in that well. The upstream well is charged with a strong electrolyte, like wetted granulated sal ammoniac, which is introduced in a perforated brass case of a diameter which can be readily inserted in the casing. When, passing gradually through the earth, the electrolyte solution reaches and enters a downstream well, it so reduces the electrical resistance in circuit that its arrival is at once indicated by a sudden deflection of the galvanometer; its gradual approach may be detected by an increasing deflection if one pole of the battery (preferably zinc to avoid polarization) be connected with the casing of the upstream as well as with that of the downstream well. This double connection is desirable when the rate of transmission is slow. From the time record the velocity is readily computed. This method has recently been applied with good results both in California and on Long Island. If the wells are not too deep, the sal ammoniac may be directly introduced in the form of a saturated solution, a bucketful being the proper charge; but if the well be deep, some uncertainty exists as to the time required to reach and fully charge the bottom, and the more complex method is usually found to be preferable.

That the flow through any given sand section is proportional to the head, and inversely proportional to the distance traversed, was discovered by Darcy near the middle of the last century, but recent filtration experiments conducted by Hazen for the Massachusetts Board of Health have also demonstrated that coefficients are necessary, taking into account the relative size of the grains, their relative cleanness, and also the temperature of the water. The formula resulting from his studies is the following, in which V is the mean velocity of flow in meters per day through the given sand cross section; C is the cleanliness constant, varying from 450 to 1,200; D is the diameter in millimeters of a sphere, the volume of which exceeds that of one-tenth of the grains forming the weight and falls below that of nine-tenths of them; H is the head; L is the distance through the sand traversed by the water; and T is the temperature of the water in Fahrenheit degrees:

$$V = \frac{CD^2 H}{L} \frac{T - 10}{60}.$$

One perplexing practical problem is often presented to engineers, What

will be the probable loss by percolation from a projected reservoir? The use of this formula has sometimes been attempted by collecting, by boring, samples of the underlying strata; but since neither the area of sand cross section to be traversed, nor the limits of local variation in C and D can be precisely estimated, no great confidence can be placed on indications thus reached. That the loss by percolation will not exceed that by evaporation from the exposed water surface has been considered sufficient and conservative in favorable localities. No precise solution seems practicable.

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## Searchlight Truck and Field Artillery Projector Unit*

The auto-searchlight equipment last evening pulled the projector unit of the Field Artillery equipment from Washington Barracks to the District of Columbia National Guard rifle range and was there used to illuminate the targets for some night firing. The searchlight was placed on a knoll some 200 yards in rear of the firing point and about 100 yards to the left of the line of fire. The firing point was in the shadow of knoll.

Major Bell, inspector small arms practice, District Militia, fired 10 shots, as follows: 5-5-5-5-3-2-5-3-5-4, making a total of 42 out of a possible 50. The 2 in the above score was fired just as the lamp mechanism of the searchlight fed, so the light flickered.

Lieutenants Tyler and Endress, Corps of Engineers, fired 3 shots each, Lieutenant Tyler making 5-3-4 and Lieutenant Endress making 2-3-5.

The above firing was from the 500-yard point on a standard mid-range target, and the battle sight was used.

The generating equipment on the auto-searchlight gives the best voltage regulation for searchlight operation of any equipment I have ever seen. Under the most severe conditions of changes in the carbons with the corresponding rapid change of current consumption from 50 to 100 amperes, the voltage applied does not vary more than 2 volts. No trouble was experienced whatever with excess heating in any part of the equipment. The equipment, for this one light, was run at 80 volts on the bus, carrying a searchlight load of 80 amperes. The only trouble experienced in this one and a half to two-hour run was bad forming of the crater in the positive carbon, making black spots occur in the beam of the light. Other than this slight trouble, the searchlight operation was perfect.

The run was made as a sort of an endurance test on the projector unit of the Field Artillery equipment at road speeds of from 3 to 10 miles an hour over various conditions of roadway. This test developed a number of weak spots in the projector unit equipment, due to the loosening up of various stud bolts and nuts. The matter is under consideration in our shops now, and I expect to replace all of the nuts that are capable of being jarred loose with some sort of patented lock nut like the Columbia, or by boring holes straight through the nut and bolt and holding with a cotter pin.

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*From Memorandum Report to Commandant Engineer School, by Mr. Earl Wheeler, Director Electrical and Mechanical Engineering Department, Engineer School.

# Selected Articles of Engineering Interest

Compiled by Henry E. Haferkorn, Librarian, Engineer School

*Breakwaters.*

Breakwater in the harbor of San Pedro, Cal. By L. C. Breed. Municipal Engineering, June, '09, pp. 372 and 373.

*Bridges.*

Collapse of a reinforced concrete bridge across the Illinois River at Peoria, Ill. Engineering News, May 13, '09, pp. 529–533. Illustrated.

Reinforcing a highway and street railway bridge. Engineering Record, May 15, '09, pp. 641 and 642.

*Canals.*

Construction work on the New York State Barge Canal. Engineering News, April 3, '09, pp. 425–439. Illustrated. (Reviews the dredging and excavation equipment, methods, dams, locks, etc.)

The New York Barge Canal. By Th. M. Ripley. Journal Association of Engineering Societies, February, '09, pp. 79–89. Illustrated.

Proposed national ship canal in Scotland (from the North Sea to the Atlantic seaboard. Engineering, London, April 23, '09, pp. 564–566. Illustrated.

*Coast Protection.*

Reclamation and development of the New Jersey coast. By George L. Watson. Canadian Society of Civil Engineers, April 15, '09. 2,500 words. Illustrated.

*Concrete.*

Fireproof qualities of concrete and other building materials. Municipal Engineering, June, pp. 365 and 366.

Method of constructing interlocking concrete pile sea walls and foundations. Engineering-Contracting, May 5, '09, pp. 347 and 348. Illustrated.

Method and cost of constructing a reinforced concrete trestle. (Condensed from an article by C. C. Mitchell.) Engineering-Contracting, May 5, '09, pp. 347–349. Illustrated.

Reinforced concrete as a fireproof material. By L. C. Watson. Cement Age, June, '09, pp. 460–463.

*Dams.*

The Arrowhead hydraulic fill dam. By F. C. Finkle. Engineering Record, April 3, '09, pp. 451–454. Illustrated.

Concerning the Gatum Dam and earth dams in general. Engineering News, April 1, '09, pp. 354–358. Illustrated.

Construction of a spillway on the Tombigbee River. Engineering Record, May 22, '09, pp. 667–669. Illustrated.

Construction work of the new dam of the Bellows Falls Canal Co. (across the Connecticut River). By Howard S. Knowlton. Engineering Record, April 3, '09, pp. 457 and 458. Illustrated.

Design of emergency movable dams for canal locks. Letter to the editor. By H. G. Tyrrell. Engineering News, June 24, '09, pp. 695 and 696. Illustrated.

Hydraulic dam construction on the Conconully Dam, Washington. By D. C. Henny. Engineering Record, April 3, '09, pp. 368–372. Illustrated.

The La Prele Dam (Wyoming). Engineering Record, April 3, '09, pp. 373 and 374. Illustrated.

The Olive Bridge Dam concrete plant (for the Ashokan reservoir in the Catskill Mountains). Engineering Record, April 3, '09, pp. 380–382.

The Pipen Brook Dam (near Stanwich, Conn.). Engineering Record, April 3, '09, pp. 388 and 389.

Undermining of a reinforced concrete dam (the Ashley Dam), at Pittsfield, Mass. Engineering News, April 1, '09, pp. 345-347. Illustrated.

*Failures.*

Failures of engineering works: Causes and remedies. By C. B. Dudley. Engineering News, July 1, '09, pp. 4 and 5.

*Floods.*

High-water marks. By Francis W. Blackford. Journal Association of Engineering Societies, February, '09, pp. 90–92. Illustrated.

*Geometry.*

The fourth dimension simply explained. By "Essayons" (pseudonym for Lieut. Col. G. D. Fitch, Corps of Engineers). Scientific American, July 3, '09, p. 6.

*Jetties.*

Improvement of the Southwest Pass at the mouth of the Mississippi River. Engineering Record, April 3, '09, pp. 439–442. Illustrated. (Describes the jetties built to increase the navigable depth.)

A complicated reinforced concrete jetty-head, Thames Haven, England. Engineering News, April 22, '09, p. 444. Illustrated.

*Locks and Lock Gates.*

Accident to the lock gates at the Canadian canal, Sault Ste. Marie. Engineering News, June 17, '09, pp. 672–674. Illustrated.

An attempt to destroy canal lock gates by dynamite. Engineering News, June 1, '09, pp. 5 and 6. Illustrated.

Bearing of the Soo Canal accident on Panama. (Editorial.) Scientific American, June 26, '09, p. 474.

Internal waterway improvements. From a lecture by Maj. William W. Harts, Corps of Engineers. Southern Electrician, April, '09, pp. 150–158. Illustrated.

Lock No. 3, Cumberland River. By Maj. William W. Harts, Corps of Engineers. Engineering News, May 6, '09, pp. 504 and 505. Illustrated.

Suggestion of a type of lock for the new Government canal at Sault Ste. Marie, including a criticism of the present Poe Lock. By George A. Burley. With com-

ment upon this paper by C. McD. Townsend, lieut. col., Corps of Engineers. Engineering News, June 24, '09, pp. 683–686. Illustrated.

*Panama Canal.*

The type of the Panama Canal. By C. E. Grunsky. Popular Science Monthly, May, '09. 9,000 words. Illustrated.

*Pavements.*

Experiments on bituminized macadam pavements. Municipal Engineering, June, '09, pp. 358–361.

Decision against the use of wood paving blocks on certain Boston streets. Engineering News, June 24, '09, p. 696; editorial, p. 693.

Causes and prevention of defects in asphalt pavements. By Isaac Van Trump. Municipal Engineering, May, '09, pp. 307 and 308.

*River Improvement.*

Colorado River breach and closure (in 1906, that flooded the Salton Basin). Engineer, London, April 9, '09, pp. 359 and 360.

Detroit River, progress on the improvement of. Engineering Record, April 3, '09, pp. 404–408. Illustrated.

Some notes on methods of making excavations in river beds by dredge and by cofferdam, with some percentages of costs. By C. Y. Dixon. Engineering-Contracting, June 23, '09, pp. 504–507.

Upper Mississippi River, improvement of. Character and construction of the improvements. Abstract of a paper by Lieut. Col. C. McD. Townsend, Corps of Engineers. Engineering News, pp. 485–488. With diagrams.

Tennessee River. Improvement of our waterways with reference to the Tennessee River. By J. N. Hazlehurst. Engineering News, May 6, '09, pp. 500 and 501. One illustration.

*Roads.*

Concrete in road construction. Cement Age, June, '09, pp. 448–450.

Experimental road work. By the Massachusetts Highway Commission in 1908. Engineering-Contracting, May 5, '09, pp. 355-359. (Treats on work with dust layers, road preservatives, binders, etc.)

The great German military road and boulevard. By H. P. Kieffer. Municipal Engineering, June, '09, pp. 349–355. Illustrated.

Instructions for making macadam roads without steam roller. By A. N. Johnson. Municipal Engineering, June, '09, pp. 355–358.

Recent specifications of the Massachusetts Highway Commission for refined tar and asphalt oils for use in highway work. By H. W. Clark. Engineering-Contracting, June 23, '09, pp. 508 and 509.

*Roofs.*

Kahn reinforced concrete roof over extension to National Gallery. Engineering, London, April 23, '09, p. 554. Illustrated.

*Sea Walls.*

Building a seawall on a sloping rock bottom. (Bulkhead wall work on East River at New York.) Engineering Record, April 10, '09, pp. 481–484. Illustrated.

Construction of a seawall at Fort Morgan, Ala. (a new concrete wall protecting the entrance to Mobile Bay). Engineering Record, April 24, '09, pp. 545 and 546. Illustrated.

*Sewage Disposal.*

Methods of sewage disposal. By Alex. Potter. Municipal Engineering, June, '09, pp. 362–365.

*Sidewalks.*

Failures in concrete sidewalks and how to correct them. By L. J. Riegler. (With specifications of the National Association of Cement Users.) Engineering News, April 1, '09, pp. 342–344. Illustrated.

Standard specifications for concrete sidewalks. Cement Age, May, '09, pp. 402–406.

*Smoke Prevention.*

Smoke Prevention. By D. T. Randall. Scientific American Supplement, June 26, '09, pp. 402 and 403.

*Surveying Instruments.*

Handyman's surveying instrument. By A. Mencken. Scientific American, July 3, '09, p. 13. Illustrated.

*Stream Flow.*

A graphic solution of Kutter's formula. By L. I. Hewes and Jos. W. Roe. Bulletin, American Institute of Mining Engineers, May, '09, pp. 453 and 454. With folding diagram.

*Trusses.*

An example of defective truss construction. By C. A. P. Turner. Engineering News, June 17, '09, pp. 655 and 656. Illustrated.

*United States Waterways.*

Report upon the proposed 14-foot deep waterway from Chicago to New Orleans. Engineering News, June 24, '09, pp. 686–692; editorial, pp. 694 and 695.

Tne waterways of the United States. By Alex. H. Weber. (Also editorial.) Engineering News, May 6, '09, pp. 492 and 493.

*Viaducts.*

A reinforced viaduct with some structural steel reinforcement, Takoma Park, Md. Engineering News, July 1, '09, pp. 6–8. Illustrated.

*Water Supply.*

A huge filtered water reservoir for London. Scientific American July 3, '09, p. 11. Illustrated.

Water supply of Superior, Wis. By William C. Lounsbury. Municipal Journal and Engineer, June 30, '09, pp. 1179–1181. Illustrated.

# Editorial Notes

The tardy appearance of the present number, caused by a conjunction of unforeseen circumstances and accidents, calls for a word of apology to our readers. It is an ill wind, however, that blows no good; for the delay has enabled valuable matter, that otherwise would have been held until October, to be published at the present time.

It will be noticed that the advertising section is steadily growing. Considering that little canvassing for advertisements has been possible, this growth is highly satisfactory. Our friends can give this important department of the magazine a helpful impetus by writing the advertisers and mentioning the magazine whenever in need of services in their respective lines. Special attention is invited to the fact that personal, as well as professional, needs are now met by the advertisements. It is hoped that this feature can be largely extended for the benefit of engineers and others at isolated stations, who are more or less dependent upon the mail in ordering articles to meet their personal wants.

The continual recurrence of criticisms of the name PROFESSIONAL MEMOIRS, ENGINEER BUREAU, U. S. ARMY, is thought to be an indication that this name is not entirely satisfactory. The words ENGINEER BUREAU appear to be the cause of most of the criticisms, and there is no question that these words fail to convey the exact meaning intended. In this way the magazine no doubt loses many subscriptions and advertisements which would come to it if its true character were understood. The suggestion has been made repeatedly that the name be changed to Professional Memoirs, Corps of Engineers, U. S. Army, as more correct and appropriate. This name was considered at the beginning, but was opposed on the ground that it implied that the magazine was intended only for the military personnel of the Engineer Department, and did not include the civil Assistant Engineers. Now, one of the ablest of these, a man of long service in the Engineer Department, comes back at us with the remark that he would rather be known as a civil engineer associated with the Corps of Engineers than as a mere employee of a bureau of the War Department. The magazine is published for the benefit of its subscribers in the Government service and of that service itself, and its name should be appropriate and exact, so as to leave no doubt as to its scope and character. An expression of opinion from those who have decided views regarding a suitable name will be appreciated.

# PROFESSIONAL MEMOIRS

*ENGINEER BUREAU, UNITED STATES ARMY*

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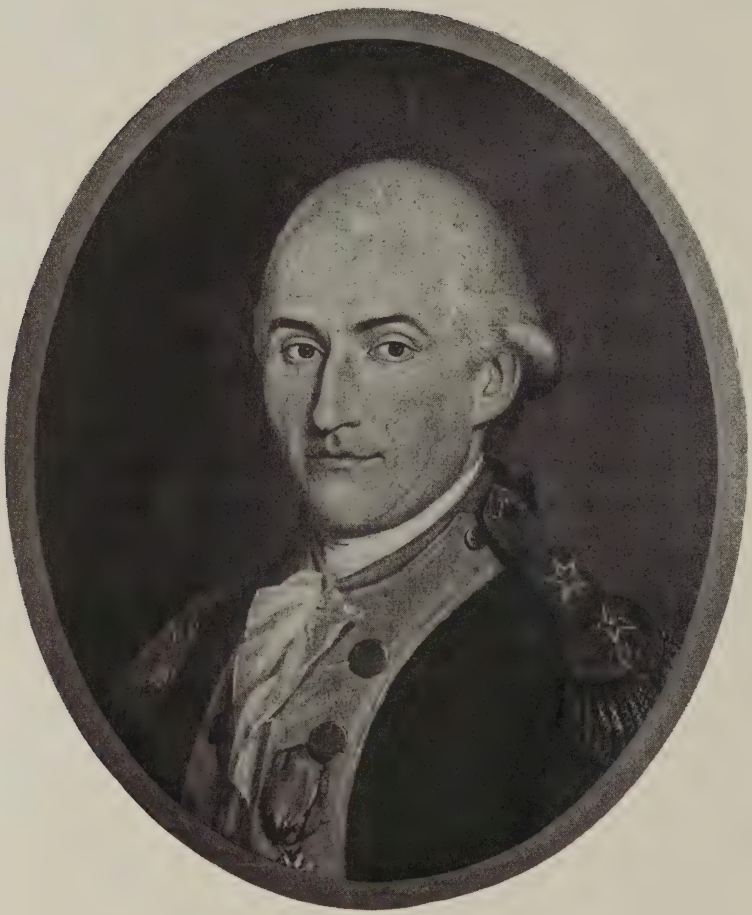


MAJ. GEN. LOUIS LE BÈQUE DU PORTAIL
CORPS OF ENGINEERS
CHIEF ENGINEER, CONTINENTAL ARMY
1776-1782
BORN 1736—DIED 1802

# Foundations on the Coosa and Black Warrior Rivers, Alabama

*BY*

D. M. Andrews
*Assistant Engineer*

Of the larger rivers lying wholly or in part in Alabama, the Chattahoochee does not leave the crystalline rocks from its source in the mountains of northern Georgia to its entrance into the Coastal Plain at Columbus, Ga. The Black Warrior lies wholly in the Paleozoic until it enters the Coastal Plain and the Cretaceous formation at Tuscaloosa, Ala. The Tombigbee, in Alabama, lies entirely in the Coastal Plain; while the Coosa lies in the Paleozoic, until, within 46 miles of Wetumpka, Ala., it enters the Metamorphic, and flows over crystalline rocks of pre-Cambrian origin to Wetumpka, where it enters the Coastal Plain.

The watershed of the Chattahoochee above Columbus contains many of the minerals of the Metamorphic, as gold, marble, asbestos, in considerable quantities. The watershed of the Black Warrior above Tuscaloosa is practically all "Coal Measures," coal in many places outcropping on the banks of the river, and frequently forming part of the rocky bed of that torrential section. Cement materials and lignite, which underlies so much of the Coastal Plain of Alabama, are the minerals of importance belonging to that section of the river below Tuscaloosa, lying in the Coastal Plain. The name Black Warrior is historically interesting, as it perpetuates the fame of Tuscaloosa, "The Black Warrior," who, with his tribe of Mobile Indians, came near annihilating De Soto and his band of adventurers at the Battle of Maubila on the Alabama River in 1540. The watershed of the Coosa above Wetumpka is rich in all the minerals of that richest of the geological eras, the Paleozoic; and in gold, marble, graphite, etc., of the crystalline rocks. Cement materials and lignite are the minerals of importance in the watershed of the Tombigbee in Alabama.

The distance from the source of the Coosa at Rome, Ga., to the

Coastal Plain at Wetumpka is 298 miles, the fall 447 feet. Of this fall, 257 feet are concentrated in the first 46 miles above Wetumpka; that is, in the section where the river flows over crystalline rocks.

From Rome to Lock No. 1, a distance of 157 miles, the river has a fall of 79 feet, and flows generally parallel to the ridges, having fashioned its bed from the softer and more unstable shales and limestones. Every few miles it encountered harder and more resistant strata of slate or sandstone; at these places occur rock reefs and shoals. This part of the river has always been navigable.

From Lock No. 1 to the beginning of the Metamorphic rocks, 46 miles above Wetumpka, the river has cut its way through the intervening ridges. At the crossings of the ridges occur prominent shoals of slate and sandstone, the remains of the harder and more resistant strata of the ridges. The length of this section is 95 miles, the fall 111 feet.

It will thus be seen that from Rome to the beginning of the crystalline rocks, and particularly in that section from Lock No. 1 down, where slackwater navigation will be required, excellent foundations for locks and dams are plentiful.

In the remaining 46 miles above Wetumpka, the river passes over many great shoals of crystalline rocks offering perfect foundations for locks and dams.

Three locks and dams, and one dam and part of a lock foundation have been built on the Coosa. These structures stand upon the sedimentary rocks of the Paleozoic.

Lock and Dam No. 1 are situated 141 miles above Wetumpka and 157 miles below Rome. These structures are founded on a compact, durable sandstone; the dam being a longitudinal, stone-filled timber crib 2,000 feet long, forming a canal from the head to the foot of Whisenant Shoals. The foundations of this lock and dam are perfect and need no further description here.

Lock and Dam No. 2, situated 138 miles above Wetumpka and 160 miles below Rome, are built on perfect foundations of hard, compact slate and sandstone. Lock No. 2 forms the upper entrance to a natural canal around Woods Island. Fig. 1 is a view of the lock, the entrance to the canal and the river below the dam.

Lock and Dam No. 3, situated 137 miles above Wetumpka and 161 miles below Rome, and controlling the lower entrance to the canal around Woods Island, are founded on a highly silicified limestone. This foundation, while very good, is not so perfect as the slate and sandstone foundations under Locks and Dams Nos. 1 and 2.

The survey of a site for Lock and Dam No. 4, and tests for

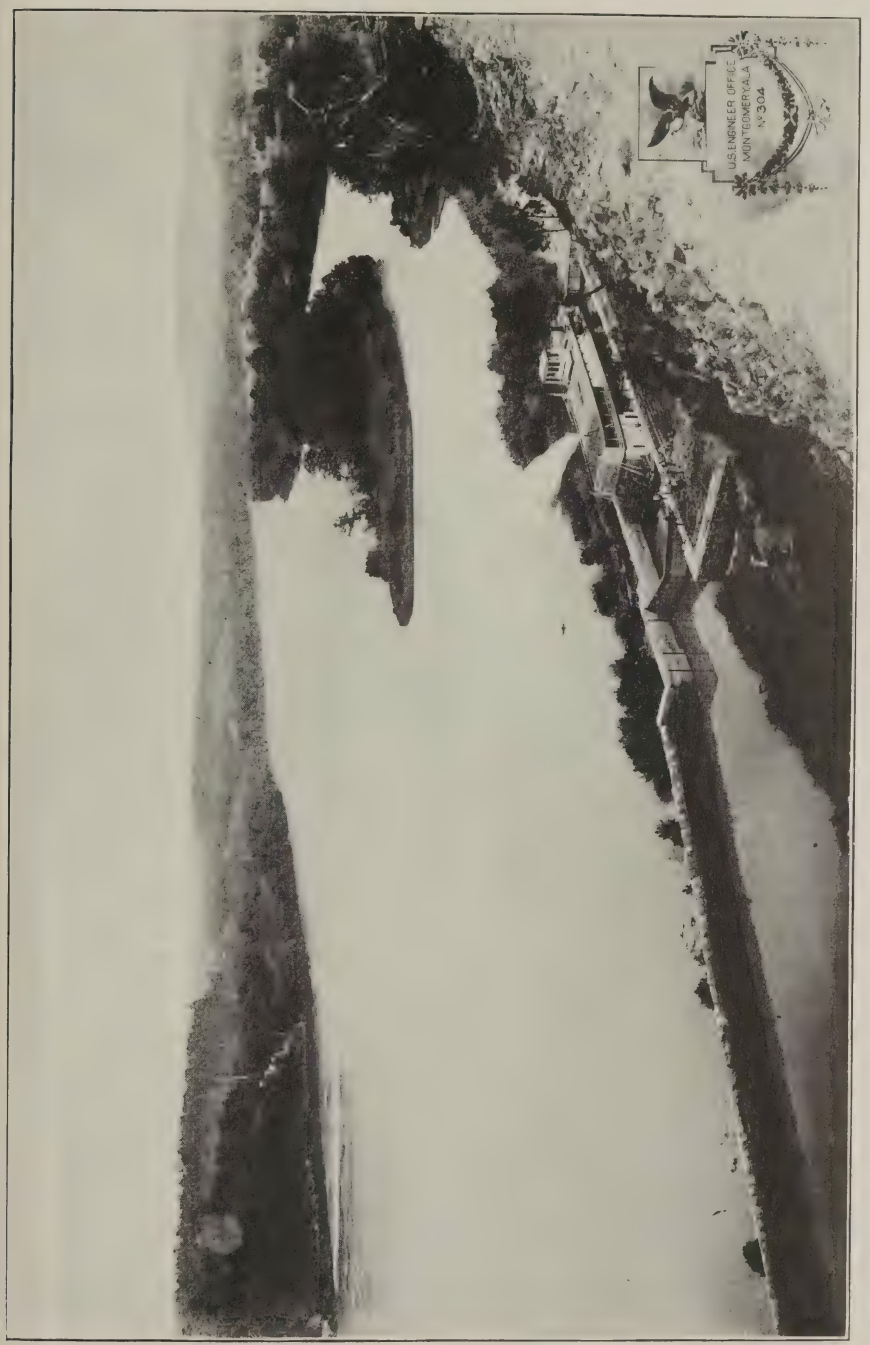



Fig. 1. Lock No. 2, Coosa River, Alabama.

foundation, were made in the summer of 1885. The site chosen is 116 miles above Wetumpka and 182 miles below Rome.

Broken-Arrow Shoals, a succession of rock reefs, 1½ miles long with a fall of 8 feet, lie about ½ mile above the site selected, and offered excellent foundation; but, as the upper pool of the then proposed Dam No. 5 did not reach to the shoal, it was necessary to place Lock and Dam No. 4 below the foot of the shoal, as was done.

On the east bank, at the selected site, there was a prominent out-

Fig. 2. Closing the break, Dam No. 4, Coosa River, Alabama.

crop of chert. This chert was *in situ* or original beds, and the course of a rock reef could be easily followed across the river by the "break of the water."

Tests of the lock and dam foundations were made with an ordinary "jumper" drill, driven with 16-pound hammers, wielded by two stalwart negroes. "Solid rock" was found under almost every test, and so noted.

When the lock foundation was laid bare in 1893, it was found that the "solid rock" consisted of honey-combed reefs; once limestone that had been replaced by silica, or that was then undergoing

the process of replacement, thus forming what is commonly known as rotten limestone.

The outcropping chert on the east bank showed the completed process of replacement or "petrification" which was still going on in the river below; and the "solid rock" reef crossing the river, whose existence was shown by the "break of the water," was honey-combed throughout its length.

The west abutment of the dam, shown in plan and elevation on Plate 1, was founded on timber piles, the tops being embedded in concrete, with a timber grillage on top of them, a single row of sheet

Fig. 3. Temporary closure prepared for season of high water, Dam No. 4, Coosa River, Alabama.

piles being driven along the face. The abutment is ashlar-faced masonry, and cost $23,373.

The honey-combed reefs in the lock foundation effectually prevented the driving of piles, and after the consideration of various plans for overcoming the bad foundation, a board of engineers was convened in Nashville, Tenn., August 26, 1896, and recommended in substance: that concrete foundation walls 9 feet deep be built under the side walls, that a 3-foot concrete floor be laid between them, and that concrete cross walls be built under the fore and tail bays, extending 6 feet below the bottom of the concrete floor. Drain pipes were to be laid under the concrete floor, and were to lead to a proper sump below the lower cross wall, to take care of the leakage when the lock was pumped out for repairs, and thus prevent the lifting of the floor. In accordance with this recommendation, three-fourths of the floor and foundation walls were built during the

summer of 1897. This structure has remained unfinished for the want of funds to complete it.

It may be of interest to know that a 2-yard cubical mixer was used in this work, and that as much as 400 cubic yards of concrete were laid per day of eight hours.

Dam No. 4, as originally built, was a stone-filled timber crib structure, having timber sheathed steps below as shown in Plate 2, and was finished in 1893 at a cost of $34,993.

During a freshet in the winter of 1896-1897, the foundation under some 300 feet of the dam was scoured out, thus permitting part of the stone filling to fall out of the crib; the upper part of the cribs relieved of the weight of the stone, gave way and floated off with the current. A section through this break, after permanent repairs were made, is shown in Plate 3 as No. 2, Section Through Break.

During the ensuing low-water season, the break was temporarily repaired by driving sheet piles along the face of the broken section, seven or eight at a time, and then bracing them, as shown in Fig. 2, until the break was closed. Just as the repairs were finished, but before the work could be secured, a timber raft came against the temporary structure during a sudden rise and carried away some 100 feet of the new work. Fig. 2 shows the floating pile-driver at work closing this second break. When the closure was made, the season was so far advanced it was necessary to secure the work at once against damage by the winter floods. This was done by sawing off the sheet piles nearly level with the crest of the uninjured part of the dam, and sheathing the braces below with heavy planking. (See Fig. 3.) During the following low-water season the sheathing over the braces was removed and the piling backed with heavy stone weighing 1 to 6 tons each, quarry waste being filled in against the upper face. This temporary work stood until 1901, when permanent repairs were begun.

Reference to Plate 3 and to Plate 1, Section Through Dam, shows the condition of much of the dam when permanent repairs were begun. The lower stepped slope had been pounded to pieces by drift, the stone filling scattered and the timber cribbing floated away.

During periods of high water a vertical eddy, shown in Fig. 4, would form below and parallel to the dam, extending at times entirely across the river. At such times rafts of "sawlogs," some of the logs 30 inches in diameter and 30 feet long, would frequently be caught and held in this eddy or backlash for hours at a time; each individual log the while going end over end, as rhythmically as the

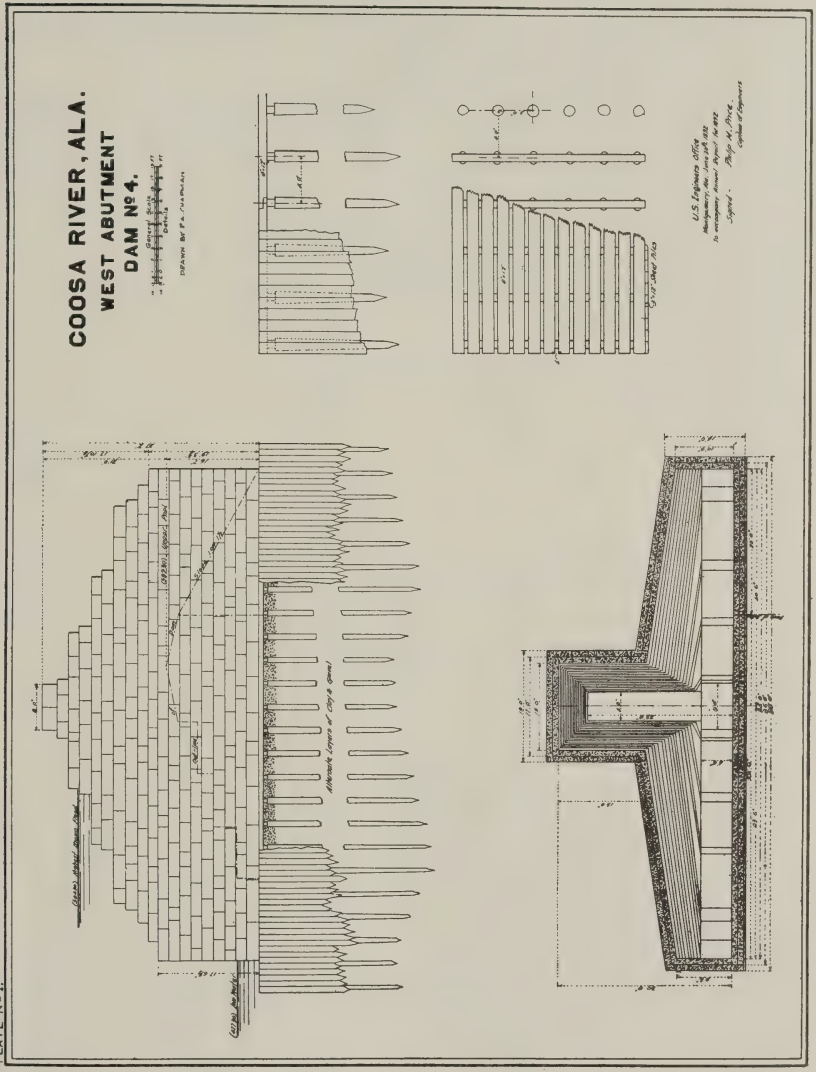



PLATE Nº 1.

fly-wheel of a well-governed engine. No timber structure could stand such punishment as this, and the result was the destruction of much of the stepped slope, and in places the gouging out of holes 10 to 15 feet deep where steps had stood, as shown in Plate 3 and Plate 1, Section Through Dam.

In 1901 an allotment was made to repair, strengthen and raise Dam No. 4 three feet by the construction of a heavy stone slope below the dam, which was to be carried over the crest in the form of an arch, and thus give the additional 3 feet of height. Quarry waste was to be filled in against the upper face of the dam. Work was commenced in August, 1901, and finished the latter part of September, 1902. In about eight actual working months, this dam, 700 feet long, with a finished lift of 15 feet, and sections as shown in Plate 3, was practically rebuilt at a cost of $42,000. Fig. 5 shows the construction of the stone slope near the middle of the river, and the method of protecting the workmen and the work from the water during construction, by means of a row of double-lap sheet piling, projecting 5 to 6 feet above the crest of the old dam, and braced from below.

The dam, as repaired and raised, has stood uninjured for a period of seven years on practically no foundation worthy the name. Its safety can be attributed to its wide base, and the long slope of the downstream face, the toe of which is protected by an apron of very heavy stone placed at random. The vertical eddy or backlash has disappeared; its disappearance being due to the change of crest and slope of lower face.

Lock No. 31 is at Wetumpka, situated at the foot of the 46 miles of rapids on the Coosa, and at the beginning of the Coastal Plain.

This lock is founded on hard, compact gneiss, an ideal foundation. The dam has not been built. It can, however, be placed on foundation similar in every respect to that of the lock whenever construction is undertaken.

Fig. 6 is a view of the Coosa rapids in the vicinity of Lock No. 31, and is typical of these rapids. It shows, also, the excellence of the foundations to be expected.

For what follows I am indebted to Mr. Geo. K. Little, assistant engineer, in local charge of the improvement of the Black Warrior River. What Mr. Little has to say concerning foundations, particularly his account of foundations—of difficulties encountered and overcome—in that part of the Black Warrior flowing through the

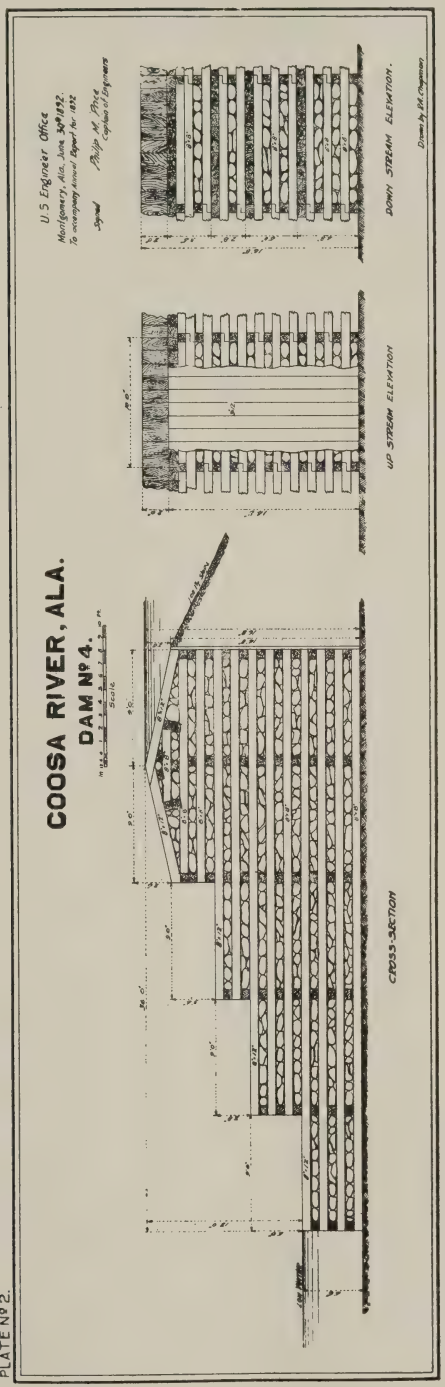

COOSA RIVER, ALA.
DAM Nº 4.
U.S Engineer Office
Montgomery, Ala. June 30th 1892.
To accompany Annual Report for 1892.
Signed Philip M. Price
Captain of Engineers
CROSS-SECTION
UP STREAM ELEVATION
DOWN STREAM ELEVATION.
Drawn by [illegible]

PLATE Nº 2.

Coastal Plain, is such a valuable contribution from actual experience, that I present it in full, as follows:

The formations over the whole area covered by the present approved project for the improvement of the Black Warrior River have a general slope of about 30 feet to the mile from northeast to southwest. The "Coal Measure," which disappears under the Cretaceous formations at Tuscaloosa, Ala., is made up of strata of conglomerate, sandstone, shale, and coal beds. That part of the river which runs through this territory is made up of a succession of pools and shoals. The shoals are formed by outcrops of sandstone, which have resisted the effects of erosion.

All locks above Tuscaloosa, beginning with Lock No. 10, are located on these shoals. No difficulty has been encountered in securing for all structures satisfactory foundations on solid sandstone.

The only change in method for future work, which has been decided on, is to use channelling machines where there is any considerable depth of rock cut, to prevent shattering the rock adjacent to the foundations.

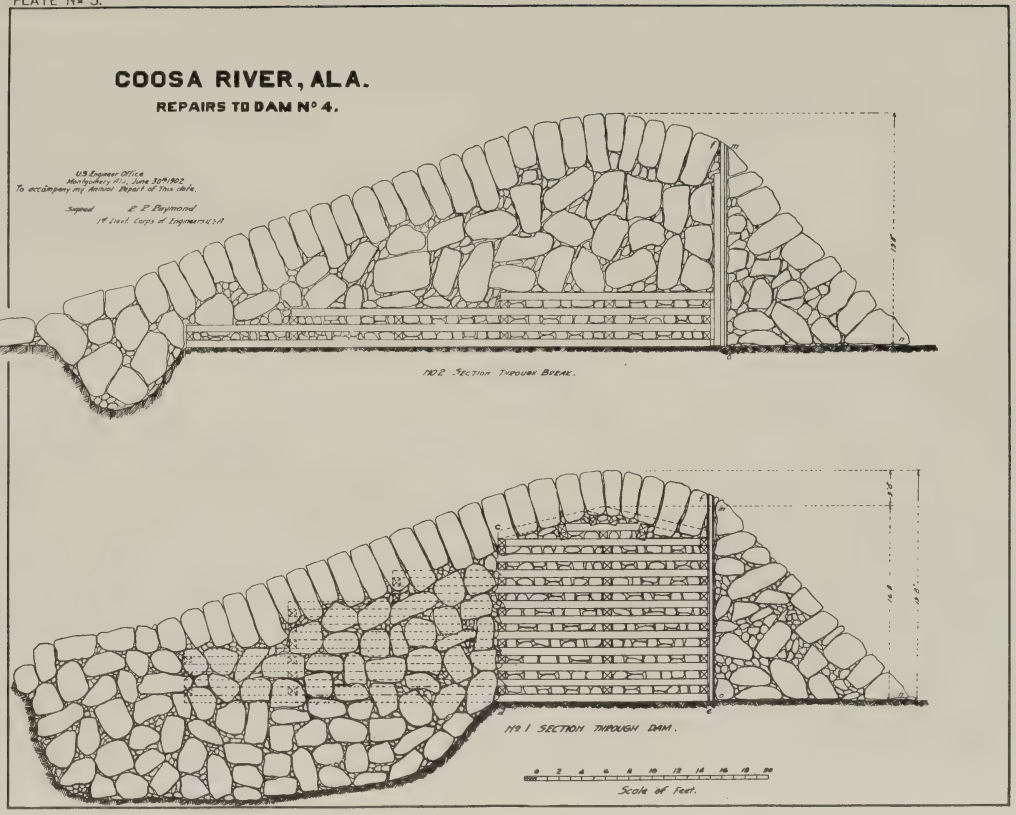
This was considered especially necessary at Lock No. 16, construction of which has just been begun, as there will be a rock-cut 11 feet deep at one point on the lock site.

Locks Nos. 9 to 6, inclusive, below Tuscaloosa, are in the Tuscaloosa and Eutaw divisions of the Cretaceous formation. The predominating material in both these divisions is sand, though there are numerous layers of gravel and clay. As no natural foundations could be found it was necessary to use pile foundations under all structures.

Locks Nos. 5 and 4 are located in the "Rotten Limestone" division of the Cretaceous formation. The material in this section is a fairly uniform clayey limestone or indurated marl. At the lock sites selected, this material was found from 3 to 16 feet below low-water line, except at the site of abutment for Dam No. 4, where it outcropped back of the abutment site in a bluff 30 feet above low water. Over most of the foundation sites it was covered with from 3 to 30 feet of clay, sand, gravel, or loam, this top covering varying considerably at points 50 to 100 feet apart. The material on which foundations were built could be cut with an ax or pick and became plastic when worked up with water, but was too hard to be penetrated by piles. Test piles were badly broomed after penetrating as much as a foot of this material.

As stated above, no difficulty was encountered in finding suitable

PLATE Nº 3.


COOSA RIVER, ALA.
REPAIRS TO DAM Nº 4.
U.S. Engineer Office
Montgomery Ala., June 30th 1902.
To accompany my Annual Report of This Date.
Signed E. E. Raymond
1st Lieut. Corps of Engineers U.S.A.
NO 2 SECTION THROUGH BREAK.
NO 1 SECTION THROUGH DAM.
Scale of Feet.

foundations at a reasonable depth for all locks and dams above Tuscaloosa. When survey was ordered to determine the location of lock sites between Tuscaloosa and Demopolis, an attempt was made to find locations where foundations could be placed on rock, hard clay, or some other material which would afford a natural foundation. No such location could be found, although borings were made at practically every possible lock site. Rock, where found, was of such a character and in such thin and irregular strata as to have no value for foundation purposes. The only alternative left was to secure sites suitable for pile foundations, and the localities showing some rock were avoided, as the thin ledges encountered formed obstructions to pile driving without any compensating advantages.

The sites selected for Locks Nos. 9, 8, 7, and 6 are thought to be the best that could have been found. The pile driving was difficult, especially where thick beds of coarse gravel or layers of tough clay were encountered. The structures consist of concrete locks and abutments and timber crib dams on pile foundations, all structures being surrounded by solid rows of triple lap sheet piling, except the downstream side of Dam No. 6, which has a solid row of round piles instead of sheet piles. There is a timber apron 30 feet wide, on pile foundation below each dam, and the locks have timber floors on pile foundations with automatic ball valves to relieve upthrust.

The most serious damage that any of these locks have sustained was the development of a large leak under the abutment of Dam No. 8, account of which is found in Annual Report of the Chief of Engineers for 1904, page 1823. This leak occurred at a point where the boring sheet shows an abrupt change from "sand" to "hard clay." The abutment proper was built on piles driven into the sand, but the rear of the abutment stem and the downstream end of lower wing rested on the clay, which was too hard to be penetrated by piles. Vertical joints were left at these changes in foundation to allow for unequal settlement. The leak developed at some time after 10 o'clock at night, and by 5 o'clock the next morning nearly the whole low-water flow of the river was running under the abutment, part of which settled down about 1 foot and moved about 2 feet toward the river.

This leak was repaired by dumping in about 25,000 sand bags and several barge loads of brush, stone, and quarry waste. After the flow of water had been shut off, further movement of the abutment was prevented by building a stone-filled timber crib against the face for 60 feet downstream from lower side of dam.

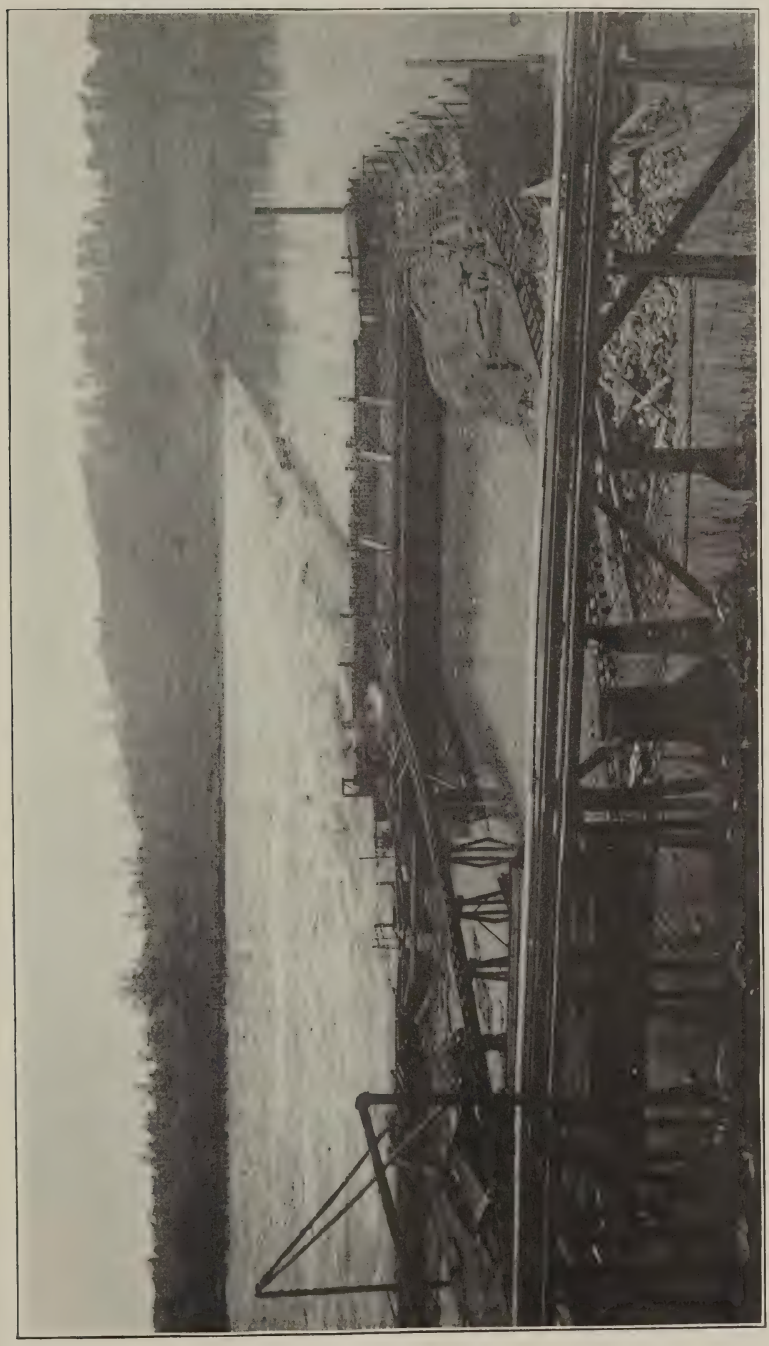


Fig. 4. Showing vertical eddy below Dam No. 4, Coosa River, Alabama.

I believe that this leak was caused by the scour below dam undermining the sheet piles along the face of the abutment, causing that part of the structure which was not founded on hard clay to slide toward the river, opening a small passage for the water.

This would probably have been prevented if a large amount of stone had been placed below the dam apron and along the exposed face of the abutment, before the work was subjected to the winter rises in river.

The sites of Locks Nos. 4 and 5 were selected for pile foundations, but during the construction of cofferdams and the driving of test piles it developed that piles could not be driven into the hard underlying material and it was decided to carry all structures down to the rotten limestone, which, when exposed by the excavation, proved to be a much firmer material than was indicated by the borings. This increased the depth of foundations in some places as much as 10 feet.

The excavation for foundations of locks and abutments at these two sites was carried down behind cofferdam protection. The dams were constructed by dredging off all overlying material down to the rotten limestone, floating the foundation cribs into place and sinking them; after which they were filled with stone and the superstructures built in place without the use of cofferdams. The timber work was kept above level all the way across the dams and several courses above the filling. From our experience on these two dams I am convinced that this method of building dams is practicable, where the amount of flow does not exceed 5 cubic feet per second per linear foot of dam under construction. After the crew employed on this class of work became accustomed to the work, they were able to keep the work going on several occasions when this amount of flow was exceeded. The only serious accident which occurred during the construction of either of these dams was in November, 1907, when the timber work on superstructure of Dam No. 4 had been carried too far ahead of the stone filling, a very rapid rise occurred which carried away about 140 linear feet of the superstructure, but did not injure the foundation.

The chief objection to the rotten limestone as a foundation is the small resistance it offers to sliding. It is thought that danger from this source has been provided against for all concrete structures by carrying the walls down at least 2 feet into the rotten limestone, and for the dams by filling considerable stone on the downstream side of foundation cribs.

Fig. 5. Constructing the stone slope, Dam No. 4, Coosa River, Alabama.

When foundation borings were made for lock sites below Tuscaloosa, the results indicated that pile foundations could be used for all structures. This proved to be the case at all sites, except Nos. 4 and 5 and part of abutment No. 8. The borings were made by the water-jet method, and in addition to the stream from a small force-pump, several different bits were used for different classes of material encountered; a rock bit for penetrating the thin ledges of rock, a gravel bit for crushing large pebbles so as to allow the fragments to be washed up through the casing pipe, and a clay bit for cutting through clay which was too tough to be washed up by the water jet alone. When the material, which was afterwards found to be rotten limestone, was encountered, the clay bit was used and no difficulty was experienced in penetrating it. The boring record shows a progress of 64 feet in eight hours through this material, which was much more rapid than the progress made in some other materials, particularly coarse gravel. This, together with the fact that the material washed up through the casing pipe was of a plastic nature, seemed to indicate a blue clay, and it was so recorded in the records. From the ease with which borings were made through this material, it was assumed that piles could be driven into it and plans and specifications were prepared for pile foundations, though provision was made in the latter, that if it was found impracticable to drive piles to a sufficient depth, all piles could be omitted and the foundations carried down to a satisfactory depth. In driving the sheet piles for cofferdams it was found to be impracticable to penetrate this material more than a few inches, and test piles driven at the same time would not penetrate more than 1 foot before beginning to broom.

This mistake might have been avoided by using a core drill instead of water-jet borings, or by providing a pile driver and driving test piles before the plans were prepared.

In the preparation of plans for Locks Nos. 7, 8, and 9, triple-lap sheet piles of 4½ inches total thickness of oak were specified. As these piles were in some cases 24 feet long, the contractor claimed that they would not be stiff enough to stand driving. He offered to substitute 6-inch pine piles at the same price per pile, which offer was accepted and proved advantageous to both the contractor and the United States. The 6-inch piles were hardly stiff enough to stand the hard driving encountered, and 9-inch piles were used for the upstream row on each dam.

When plans were prepared for Lock No. 6, 9-inch piles were specified for all sheet piling, and proved much more satisfactory in prac-

tice. On part of the work the contractors were allowed to use the plank in two lengths, breaking joint, but this was found to reduce the stiffness to such an extent that after a short trial, full length plank were required in all sheet piles.

In the original plans for Locks Nos. 7, 8, and 9, no provision was made for the prevention of scour below the dams, except the construction of timber aprons 30 feet wide. This provision proved to

Fig. 6. Rapids on Coosa River, Alabama, near Lock No. 31.

be entirely inadequate, and parts of two of the aprons were undermined from the downstream side, the apron planks being torn up by the backlash below the dams. In some cases, the river bed below the aprons was scoured out to a depth of 27 feet below low water during one high water season. As soon as possible after this scour began, stone was delivered from the quarries above Tuscaloosa and large quantities dumped below the dam aprons, along the back of river walls and along abutment faces. During the next low-water season the dam aprons were covered with a rough paving of derrick stone.

As soon as Dam No. 6 was completed, and before being exposed to high water, considerable stone was filled below the dam apron and along the exposed faces of lock and abutment walls. No serious scour has, as yet, been detected at this lock and dam.

At Locks Nos. 7, 8, and 9, the walls were surrounded by sheet piles, but the heads of the piles were not embedded in the concrete of the lock walls.

The foundations of walls were carried only 1 foot below the floor level, which afterwards proved to be hardly sufficient.

When the scour above referred to occurred on the outside of the river walls, the material on the outside was in some cases eroded to below the level of the lock floor. When the walls were exposed to the full head of water from the inside while lockages were being made, the pressure from within shoved the walls over enough at Locks Nos. 8 and 9 to open the joints between the timber floors and walls of the locks.

This movement of the walls caused considerable leakage, the water passing from the lock chamber, under the walls and out over the tops of enclosing sheet piles. At Lock No. 9 the leakage was not excessive, and after considerable stone had been filled along the outside of the wall, to prevent further scour and any further movement of the wall, a diver was able to calk the leak successfully from the inside by driving cypress shingles in the joint between the floor and the river wall. At Lock No. 8 the leakage was so great that it was decided to pump out the lock for repairs. When coffer timbers were placed across both ends of the lock, two 8-inch centrifugal pumps were not sufficient to empty the lock chamber. A levee of dredged material was then thrown up along the outside of the wall, and the lock chamber was pumped out without further difficulty.

The joint between the floor and river wall was found to have opened up to nearly 2 inches in one place, and varied from that width to a close joint. The open joint was calked and covered with battens, and the levee of dredged material on the outside of the river wall was protected with spalls and quarry waste, after which it was covered with a rough paving of derrick stone, similar to that used on the dam apron. The above repairs were made in 1904, and no trouble has been experienced with Lock No. 8 since that time. At Lock No. 6, recently completed, all sheet-pile heads were embedded in concrete to prevent leakage and to take advantage of the bearing value of the piles.

The timber floors at Locks Nos. 7, 8, and 9, were formed by driv-

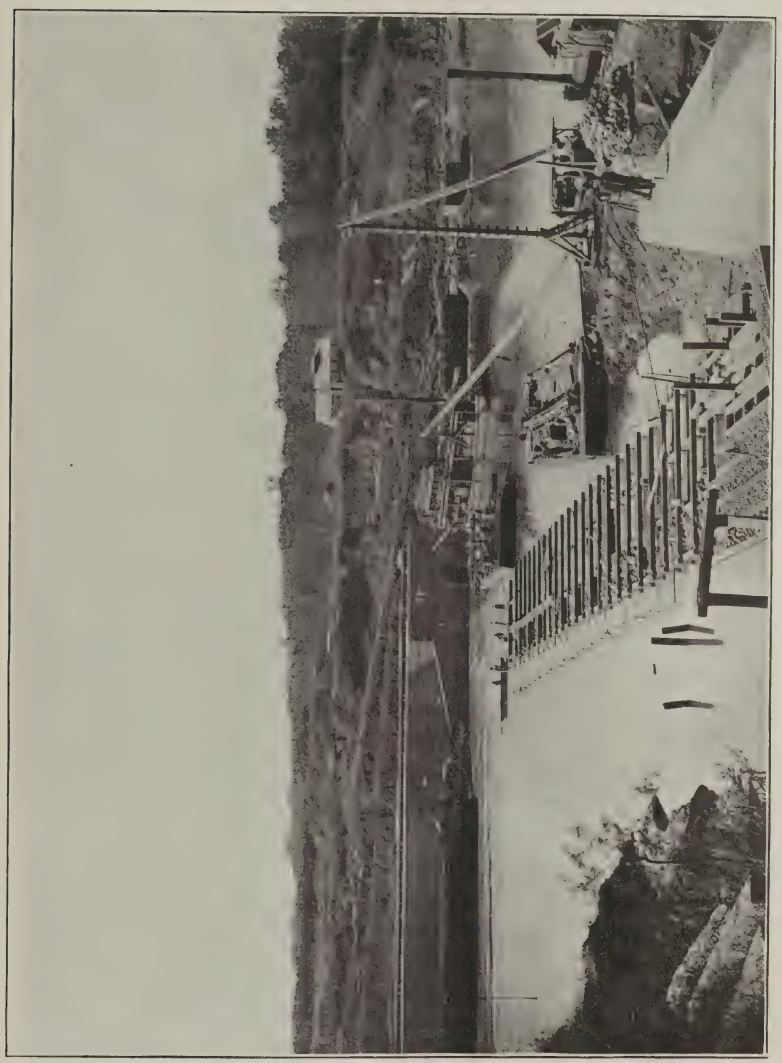


Fig. 7. Crib foundation for stone-filled timber dam, Lock No. 4, Tombigbee River, Alabama.

ing piles in rows 6 feet 2 inches apart, the piles in each row being 8 feet between centers. Caps, 10 inches by 10 inches, were drift-bolted to these piles, and the floor, consisting of one layer of 3-inch and one layer of 2-inch plank, was spiked to the caps.

During 1902, before all construction work had been completed at Lock No. 8 and while the lock gates were being erected, there was a head of about 7 feet against the lock walls from the outside. The pressure from below, due to this head of 7 feet, lifted the floor to such an extent that it was necessary to replace it. The caps were found to have lifted from the pile heads. Additional piles were driven so that the spacing in rows was 4 feet, and additional rows were driven between, making rows 3 feet 1 inch apart. The pile caps were replaced and secured by nailing 2-inch by 12-inch straps on both sides of caps and pile heads. The piles in alternate rows were cut off level with the bottom of the plank floor and the heads dove-tailed. Caps, 3 inches by 12 inches, were then placed on each side of these piles and bolted through with machine bolts. The flooring was then spiked down to the caps, and has since shown no tendency to rise. The floor at Lock No. 7 raised about 2½ inches in one place, but has never been repaired and has caused no trouble.

The floor at Lock No. 6 was built on piles spaced 4 feet by 3 feet 1 inch centers, with heads dovetailed and caps bolted to sides of piles. This floor is made of three layers of 2-inch plank, spiked down to the caps, and has given no trouble. Valves to relieve upward pressure are used in all floors.

It was the original intention to build all dams, below Tuscaloosa, on pile foundations without the use of cofferdams. This was done successfully only at Lock No. 7. In attempting to make the closures in lines of sheet piles at Locks Nos. 6 and 9, the current, when confined, scoured out the river bed to such a depth as to undermine the piles, and render a cofferdam necessary before a closure could be made. I believe these dams could have been built as originally intended, if all sheet piles had been cut off at such a depth below low water as to cause a head of not more than a few inches. This could have been done only at or very near a low-water stage.

One of the most difficult foundation conditions which has been found on this river is the small resistance to sliding offered by the rotten limestone foundations at Locks Nos. 4 and 5. There has been no trouble with the masonry walls, as they were founded in trenches in this material, not less than 2 feet deep, but on several occasions when cribs were placed on top of this formation they have been

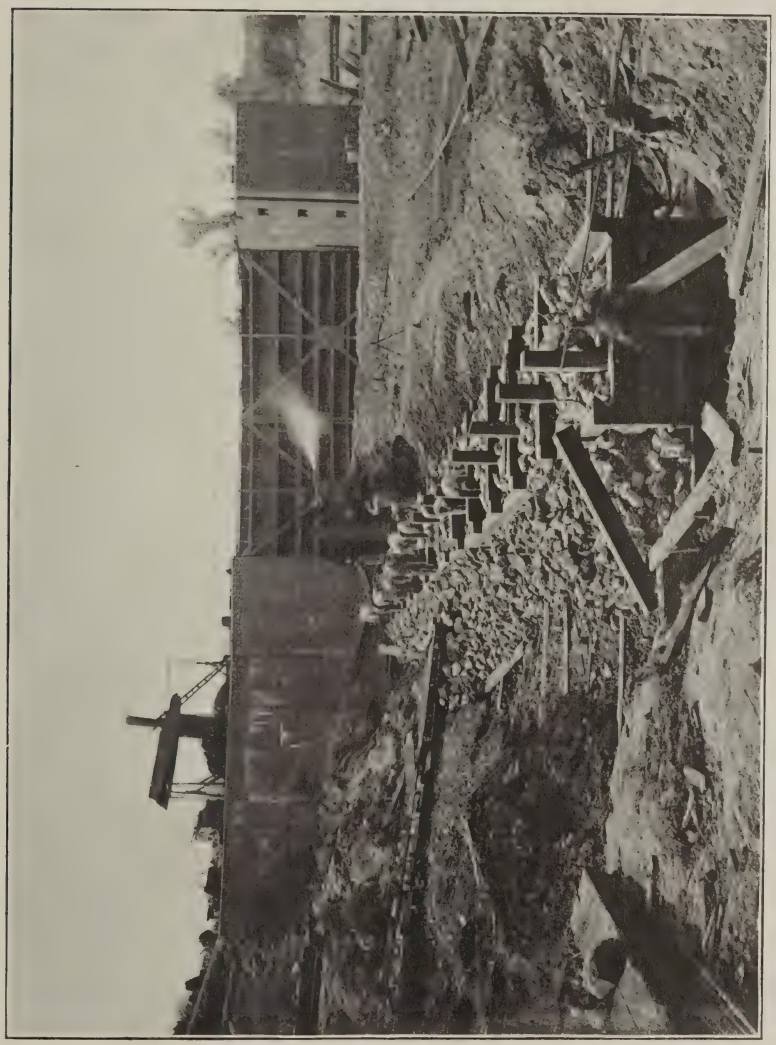


Fig. 8. Foundation for retaining crib, Lock No. 4, Tombigbee River, Alabama.

forced out of place by pressures that were not sufficient to overturn them. Once, when an attempt was made to cofferdam for a section of the dam a crib 20 feet wide, 40 feet long and 20 feet deep, which was about three-fourths filled with stone, was slid about 40 feet downstream, by a head of not more than 5 feet. This crib did not tip over at all, and was not broken up except for a few timbers which were fastened to an adjoining crib. On another occasion a crib 14 feet high, with a 16-foot base, completely filled with stone, and with the back filling sloping back from the top with a slope not steeper than 1 vertical to 5 horizontal, was shoved out of line several feet. On this occasion the bank cracked back on top about 100 feet from the crib, and seemed to settle down almost vertically along the line of the crack, and to shove out horizontally at the bottom. The material overlying the rotten limestone back of this crib was so stiff that it could be cut to a slope almost vertical, but would gradually creep out several feet during the night. It is thought that this crib would have held if set in a trench 2 or 3 feet deep, and strengthened to prevent its shearing off at the top of the rotten limestone.

The work below Demopolis on the Tombigbee River is not carried on under this office, and I will only make brief mention of the foundations.

Lock, Dam and Abutment No. 1, located on McGrews Shoals, are built on a formation of soft, Tertiary limestone, which crosses the river at this place. This foundation seems satisfactory in every way, except that it is doubtful if it will withstand the scour below the dam without some additional protection. A concrete apron was built just below the dam and it is the intention to fill in some stone just below the apron.

Locks Nos. 2 and 3, Tombigbee, now under construction, are to be founded on a hard, black, lignitic clay of the Tertiary formation. The locks and abutments will be of concrete, founded about 2 feet below the surface of this indurated clay, and the dams will be stone-filled timber cribs on crib foundations, similar to those used at Locks Nos. 4 and 5.

# THE PANAMA CANAL*

*BY*

LIEUT. COL. H. F. HODGES
*Corps of Engineers*

The history of the attempts to establish connection between the Atlantic and Pacific oceans across the American Isthmus is very interesting, and dates back to the time of the first crossing by Balboa from Caledonia Bay to San Miguel Bay in 1513.

The first commercial route was that laid out from Old Panama to Nombre de Dios, crossing the Chagres River at Cruces, which lies about 2 miles above the point at which the line of the present projected canal leaves the river valley.

The Atlantic terminus of this road was moved from Nombre de Dios to Porto Bello, when the latter place became the important seaport on the Caribbean Sea, and it was used for many years for the carrying of merchandise and silver from the warehouses at Old Panama for shipment in the galleons waiting at Porto Bello. It was this road which was followed by Morgan's men in their raid, which resulted in the destruction of Old Panama in 1671, two years after the same bloody leader had sacked the seaport of Porto Bello. The road is still in existence, and, although the greater part of it is swallowed up in the jungle, many miles of it may still be followed, and in parts the pavement is to-day in almost perfect condition.

Beside the crossing thus established on the Isthmus of Panama other routes were followed, particularly the one at Tehuantepec, but the establishment of all these land roads was incident to the search at first for a natural avenue of water transportation and, later, for the most practicable route by which an artificial waterway might be established. This search was prosecuted by Spain with vigor in the early part of the sixteenth century, but later was laid aside and not actively resumed by the mother country until shortly before the loss of her Central American provinces, which caused her to abandon it altogether.

The project, however, was one in which the entire civilized world

*An address delivered June 10, 1909, before the Engineers Society of Pennsylvania.

was interested, and other nations also undertook investigations looking toward carrying it into effect.

No less than nineteen different routes have received consideration and more or less careful examination. Of these the Tehuantepec, Nicaragua, Panama and Darien lines are the four principal ones, and among them those by way of Lake Nicaragua and of Panama have been most prominently before the public in recent years. Both have had their advocates, and companies have been formed and concessions granted for the prosecution of both enterprises.

The first commercial fruit of these concessions was the existing Panama Railroad, based upon a grant by the Government of New Grenada (made originally to a French company in 1838), and covering roads, railways, or canals. After very inaccurate preliminary investigations and reports, the French Government took up the matter and sent an engineer named Napoleon Garella, who, in 1844, made an accurate report, recommending the construction of a canal.

No results followed this report, and the concession to the French company lapsed. Another was granted in 1847 to a second French company, but was later withdrawn, and subsequently, in December, 1848, was granted to Messrs. Aspinwall, Stephens, and Chauncey, representing an American organization. Through their efforts the Panama Railroad Company constructed its road from Aspinwall (now Colon) to Panama between 1850 and 1855, and by a subsequent modification of the original charter the company acquired exclusive rights within a certain territory for a period of ninety-nine years, beginning in 1867.

After the Civil War the United States Government renewed efforts looking toward the establishment of maritime communication across the Isthmus. The line was surveyed in 1875 from Limon Bay to the Pacific terminus south of Panama, and this line has been followed substantially in subsequent projects.

In 1876, before the United States took further measures, a French association obtained exclusive concessions from the Colombian Government covering the entire territory of the republic, contingent, however, upon its quieting any claim which should arise, due to the infringement of the existing rights of the Panama Railroad Company. The association then convoked a congress, known as "The International Congress of Surveys for an Interoceanic Canal," which met in Paris in May, 1879. The action of this congress appears to have been swayed by the influence of M. de Lesseps, and it pronounced in favor of the sea-level canal from the Bay of Limon to

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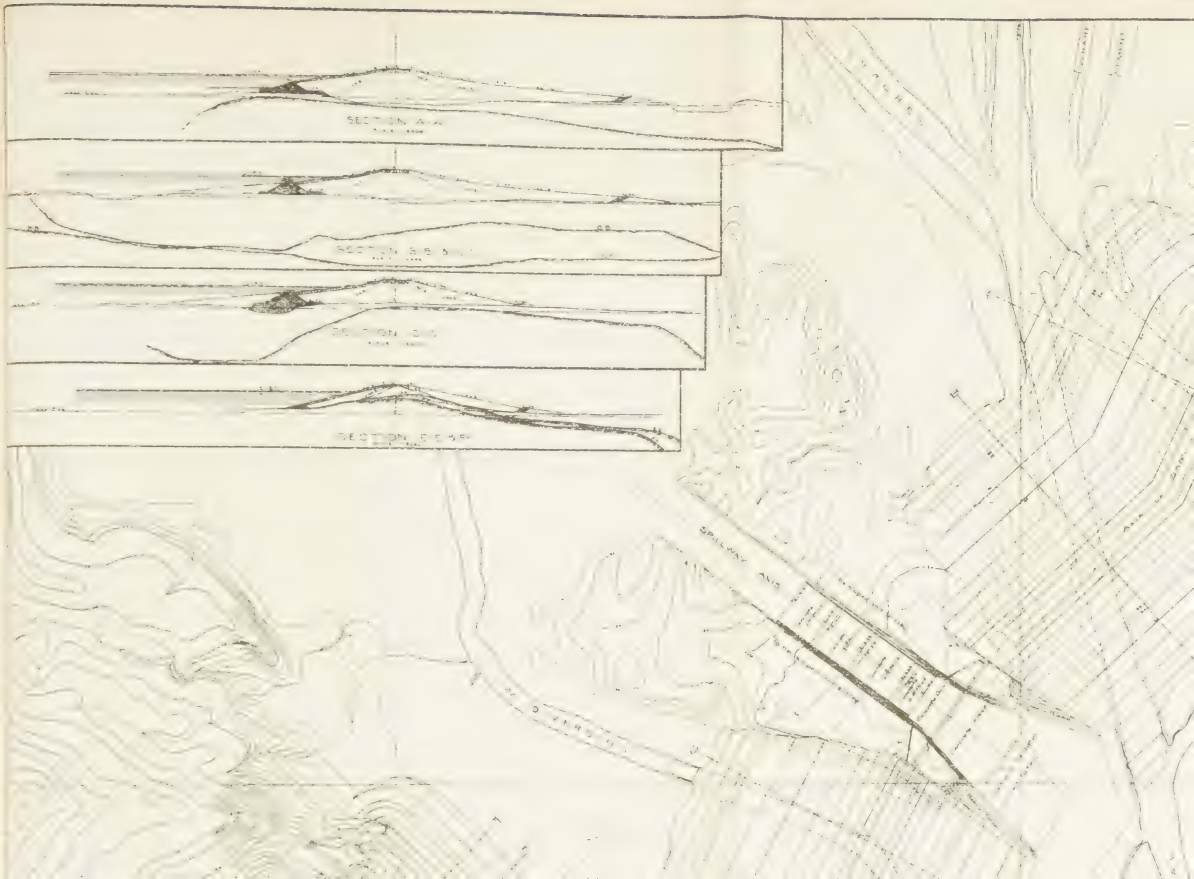
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Panama Bay, estimating the cost at about $240,000,000, including interest; and the time of completion at twelve years. It is interesting to note, in this connection, that out of the one hundred and thirty-five members of the congress only ninety-eight were present when the sea-level resolution was passed, and only seventy-eight voted in favor of it, and it is stated that the majority of the engineers and contractors present at the congress were opposed to the resolution.

Immediately after the congress the Universal Interoceanic Canal Company was formed, with M. de Lesseps at its head. This company purchased a controlling interest in the Panama Railroad, thereby insuring itself against any claims from that source, and entered upon the work of constructing the canal. It was at first the intention to let the entire construction as one contract, but after preliminary measures had been taken, objections which were deemed controlling were found, and the work was subdivided into several smaller contracts.

In the meanwhile the estimates of the congress had been modified, reducing the cost and time. Until 1887 the work proceeded along the sea-level plan, it being intended to exclude the Chagres River from the canal by a dam at Gamboa, and to carry its waters and that of the other rivers to the sea through diversion channels to be opened on either side of the canal and approximately parallel to it.

In 1887 the financial difficulties of the company, and the evident impossibility of completing the work with the funds available, or within the estimate, led to the substitution for the sea-level plan of a plan involving a temporary lock canal. The surface of the summit level of this canal was to be about 160 feet above sea level. The construction of the locks was provided for by contract, and the excavations for these locks may still be seen at certain points of the existing canal prism.

Failure of the company to place its bonds, even after this change of plan, resulted in its downfall, and in February, 1889, it passed into the hands of a receiver.

The company expended in various ways about $260,000,000, and accomplished about 72,000,000 cubic yards of excavation.

The New Panama Canal Company was formed in October, 1893, and resumed operations on the canal, principally in the Culebra Cut. This company continued its work until the enterprise was finally taken over by the United States Government.

It accomplished about 10,000,000 cubic yards of excavation, principally in the Culebra Cut, and the investigations which it undertook

of all questions bearing upon the construction of the canal were very thorough and of great value.

The plan which the company followed contemplated a lock canal with two levels above the sea—one of them an artificial lake to be created by a dam at Bohio, and reached from the Atlantic side by a flight of two locks. Above this was the summit level, with its bottom 68 feet, and its surface 102.5 feet above sea level, and with a bottom width of about 98 feet. This summit level was to be supplied with water through a feeder reaching from a reservoir made by a dam at Alhajuela on the upper Chagres River. On the Pacific side were also four locks at Paraiso, Pedro Miguel, and Miraflores, the two middle locks being combined in one flight. The locks were to have twin chambers, each with usable dimensions of 738 feet in length and 82 feet in width.

In addition to this plan the engineers also had another one in view, in which the upper level was omitted and the cut through the ridge was correspondingly deeper. The dam at Bohio was retained and the Chagres was allowed to flow directly into the lake, which became the summit level. Between Bohio and the sea the canal was to be paralleled by diversion channels, the reservoirs above the Alhajuela Dam and Lake Bohio were counted upon to retain a portion of the flood of the river, and a system of sluices and regulating works was devised to keep the portion admitted into the diversion channels below Bohio within the capacity of these channels.

The first few years' work on both these projects would have been useful on either, and it was the intention of the New French Canal Company to make use of the second low-level plan in case its experience should indicate such a course as wise.

On March 3, 1899, the Congress of the United States passed an Act empowering the President to make full and complete investigations of the Isthmus of Panama, with the view to the construction of a canal. He was authorized to investigate any and all practicable routes, and especially the Nicaragua and Panama routes. Under authority of this Act an Isthmian Canal Commission was appointed by the President, which reported in November, 1901, in favor of the Nicaragua route, having in view the fact that the existing New Panama Canal Company demanded for its rights and property the sum of $109,000,000, which sum made the estimated cost of the canal by the Panama route exceed that by the Nicaragua route. After subsequent negotiations with the New Panama Canal Company, which resulted in the withdrawal of its previous demands, and an offer to

transfer its rights and property to the United States Government for $40,000,000, the Commission, in January, 1902, submitted a supplemental report in which it favored the Panama route. Congress then, in June, 1902, passed an Act empowering the President to proceed with the construction of the canal by the Panama route in case the rights of the New Panama Canal Company could be purchased for $40,000,000, and suitable arrangements could be effected with the Republic of Colombia regarding the control of the necessary strip of land; and in the event of failure of either of these negotiations, to adopt the Nicaragua route. Under this law the rights of the New Panama Canal Company were acquired for the sum of $40,000,000, the sum of $10,000,000 was paid to the Republic of Panama, the successor of the Colombian Government in this region (both of these Acts being accepted in subsequent legislation), and the construction of the canal has since been in progress.

There is no doubt that the United States Government received full value for the $40,000,000 paid to the New French Canal Company. In return for this amount it acquired about 30,000 acres of land, which, with the land belonging to the Panama Railroad Company, constituted a great part of what had to be acquired for the construction of the canal, the remainder being purchased later from private holders for less than $300,000. It also acquired all the buildings, plant, and other property belonging to the company, the work done by that company, which amounted to nearly 40,000,000 cubic yards of usable excavation, and practically all the shares of the Panama Railroad Company.

The excavation alone was worth nearly the whole sum paid to the company. The plant has also proved of considerable value; much of it has been restored and used. We have had as many as two hundred of the French locomotives in service, seven hundred or eight hundred of their dump cars, and we have built seven ladder dredges out of fragments of others, these dredges alone being worth, in the aggregate, at least $500,000 to the Commission. The railroad also is not only a valuable property, worth several millions, but is indispensable in the canal work.

The type of the canal to be adopted was decided by Congress in accordance with the minority report of a Board of Consulting Engineers appointed in 1905 by the President from men distinguished in their profession in all parts of the world. This Board consisted of five members from European countries and seven Americans; of these five foreigners and two Americans were in favor of a sea-level

canal, while five Americans, citizens of the country which will have to foot the bills, were in favor of the lock type of canal.

The sea-level canal recommended by the majority of the Board was to be 150 feet wide at the bottom in earth cutting and 200 feet wide in rock cutting. It was to follow a line consisting practically of a series of curves, and was to have a tide lock at the Panama end.

It must be remembered that the tidal oscillation on the Pacific Coast reaches an extreme of 20 feet from high water to low water, while that on the Atlantic Coast is only 2 feet. Even in a sea-level canal, therefore, a tidal lock is a necessity, unless the waterway be made of such enormous cross section that the varying currents generated by this different tidal oscillation would not prove injurious to navigation.

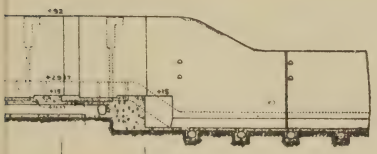
The old enemy of the canal, the Chagres River, was to be cared for by the construction of a large dam at Gamboa forming a reservoir. Regulating devices were proposed by which the waters of the Chagres were to be admitted to the canal at a maximum rate of 15,000 feet per second, greater flood discharges being temporarily absorbed by the reservoir. Even this assumed maximum was calculated to produce a current of 2.6 feet per second in the canal.

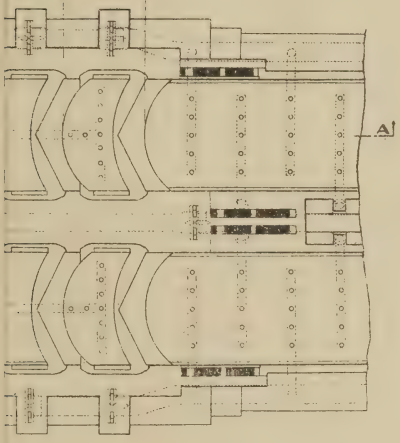
The main tributaries from the west were to be cut off by minor dams, of which four were to be built, and carried to the sea by diversion channels; while certain of the smaller tributaries were to be taken into the canal directly.

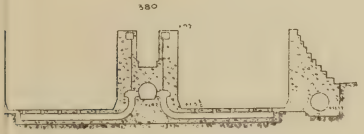
The time of construction was estimated at twelve or thirteen years by the Consulting Board, and at eighteen to twenty years by the Canal Commission.

In its consideration, which resulted in the recommendation of the sea-level type, the majority of the Board of Consulting Engineers compared its plan with a lock canal involving a summit level of 60 feet above sea level, and two locks on either slope, those on the Atlantic side to be placed at Gatun and Bohio, and those on the Pacific slope at Miraflores.

The minority of the Consulting Board, consisting of the five American engineers to whom reference has already been made, favored the adoption of the lock canal with summit level of 85 feet above mean tide. This summit level was to be maintained by a great dam at Gatun, and a smaller dam at Pedro Miguel, making a lake 164 square miles in area. From this level vessels were to be passed at Gatun to the sea level by a flight of three locks, and at Pedro Miguel to a lake 30 feet lower, formed by a dam at La Boca.






Section H-H

ISTHMIAN CANAL COMMISSION

DEPARTMENT OF CONSTRUCTION AND ENGINEERING
OFFICE OF THE CHIEF ENGINEER
CULEBRA, CANAL ZONE

GATUN LOCKS

GENERAL PLAN AND SECTIONS OF UPPER LOCK.

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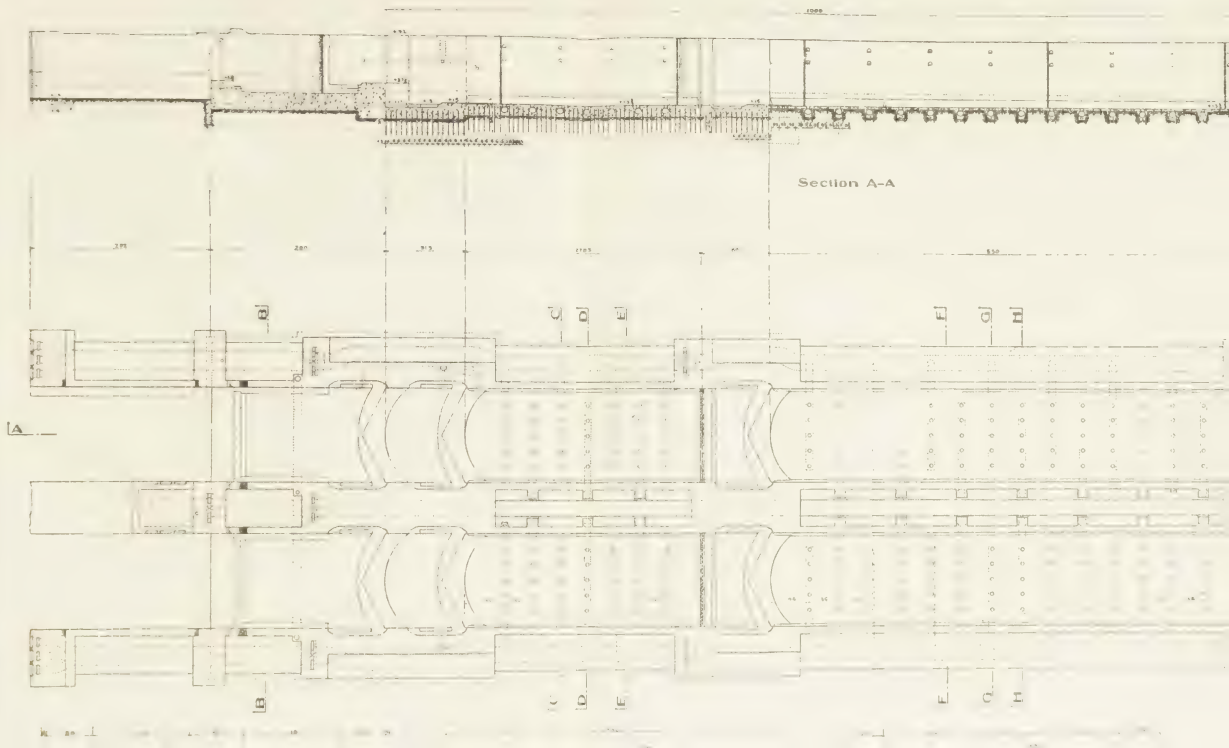
THE NORRIS PETERS CO., WASHINGTON, D. C.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Through the last-named dam the sea level of the Pacific Ocean was to be reached by means of a flight of two locks. The prism of the canal was to be 200 feet wide in the Culebra Cut, and for the remainder of the distance 300 to 1,000 feet wide. The least depth was to be the same as that adopted in the sea-level plan—namely, 40 feet—and the locks as originally recommended were to be 900 feet long and 95 feet wide. The estimated cost of this canal was about $140,000,000, or more than $100,000,000 less than that of the sea-level canal, and the estimated time of completion was nine years.

The plan favored in the minority report was also favored by the majority of the then existing Isthmian Canal Commission, all but one member supporting it. It was also strongly endorsed by Mr. John F. Stevens, then chief engineer of the Commission. It was warmly recommended by the Secretary of War, who, however, reserved his support as to certain points, particularly the location of the locks on the Pacific slope; and it was recommended for adoption to Congress by the President. Congress adopted it by the Act of June 29, 1906, which provides that "a lock canal be constructed of the general type proposed by the minority of the Board of Consulting Engineers," and under this plan, with some modifications, the work has since been proceeding at a rate which promises its completion within the estimated time of nine years from the date of the adoption of the plan.

The principal ones among the modifications alluded to are the removal of the dam and flight of two locks on the Pacific from La Boca to Miraflores, the widening of the Culebra Cut from 200 to 300 feet, and the increase in the size of the locks to 1,000 feet long and 110 feet wide.

A few words may not be out of place here on the main points which should be considered in comparing the relative merits of the sea level and lock types of canal as proposed by the Consulting Board and now in process of construction.

The ruling features, as a matter of course, are suitability for navigation, cost, and time of execution. It may be accepted that the ideal channel between two bodies of water is one with no change of level, and with a width and depth imposing no restrictions upon navigation; but who shall say that this ideal would be realized by any channel humanly possible of construction across the Isthmus of Panama between two oceans whose relative level may and does vary with the tide by as much as 20 feet?

The natural divide between the two oceans on the route followed

by the sea level was 333 feet high above mean tide on the center line when first attacked by the French, and more than 500 feet high where cut by the eastern side slope.

In the Cut through this divide, popularly known as the Culebra Cut, the lock-canal project offers a channel 300 feet wide at the bottom, and the sea-level canal one only 200 feet wide. For the remainder of the way the sea-level canal follows the curves of the natural surface, thereby decreasing the amount of excavation, and offers a channel only 150 feet wide at the bottom, in which currents up to 2.6 miles per hour may exist, due to the discharge from the Gamboa Dam. To adopt a course with fewer curves and a wider channel would increase correspondingly the volume of the material to be excavated. The lock canal, on the other hand, follows a series of long tangents connected by curves of convenient radii, and offers a channel, which, outside of the Culebra Cut and the lock chambers, is nowhere less than 500 feet wide, and is 800 to 1,000 feet wide for 19 miles of its course.

By either type of canal, the distance from shore to shore is about 42 miles. Through this distance the sea-level project presents a narrow channel, with curves such that for 19 miles a vessel would have to proceed with much caution, and whenever it should meet another vessel one or the other would have to stop and tie up. For the corresponding distance in the lock canal the courses are reasonably long and straight, giving a clear view ahead. The bottom width will permit vessels to pass without tying up. For the first 15 miles from the dam at Gatun through the lake the width is 1,000 feet; for the next 4 miles the vessels must proceed through a channel 800 feet wide, and from 4 miles farther on through a channel 500 feet wide. For the full distance of 23 miles from Gatun to Bas Obispo the shores of the lake are distant from the channel and there need be practically no speed limit enforced. Even through the deep cut from Bas Obispo to the lock at Pedro Miguel the width of 300 feet will permit of easier navigation than the width of 200 feet adopted for the sea-level canal. In such a channel there is no difficulty in vessels passing each other.

One can readily see that the amount of excavation in even the narrow canal projected by the majority of the Board is vastly in excess of that involved in the 85-foot level project. Nevertheless, the great problem of the sea-level canal is not that of removing this material, but rather that of controlling the Chagres River. The attempt was made by the first French canal company, and was neces-

sarily abandoned after vast sums had been sunk. It requires great dams, reservoirs, and diversion ditches, the magnitude of these subsidiary constructions being hardly less than that of the main canal prism.

On the other hand, the lock canal converts the Chagres from a formidable enemy of the project to its main support and friend, by creating an artificial lake in the valley of the river, which serves as a reservoir of sufficient capacity to absorb floods without injurious effect, and to store them until the failure of the rain during the dry season shall make it necessary to draw upon the reserve thus formed for lockage purposes.

The dam forces the water of the reservoir so far up the valley of the upper river that the shock of the floods will not be felt in the lake itself. At the same time the broad channel in the lake, unrestricted by the rocky banks of the sea-level cut, affords to navigation far better facilities for speed and safety.

Much has been made by the upholders of the sea-level plan of the dangers supposed to exist for vessels in passing the locks of the adopted type. Without at present dwelling upon the many safeguards which are proposed in the plans for these locks, which you will see later, I will touch only upon what experience has shown in some existing locks built without such elaborate precautions.

We are favored in this country with the existence of a canal of the lock type, which carries now and has for years carried many times the volume of commerce now or ever carried by the greatest of sea-level canals. This canal exists on the St. Marys River, connecting Lake Superior with Lake Huron, and has been in use since 1855. There are now two canals—one on the Canadian side and one on the American side. There is one lift of about 20 feet. The Canadian canal has one lock and the American canal two, side by side, with a third now authorized and in process of construction. Between 1890 and 1907, 312,734 vessels, with more than 460,000,000 tons of freight, passed the canal. The largest lake vessels go through it, and since the beginning of its operation there has been no accident on the American side serious enough to cause more than a few days' suspension of lockages. The longest suspension which has taken place there was caused not by any accident in which a vessel figured, but by the breaking of one of the lock valves.

Until June 9th, last, practically the same immunity from serious accident was possessed also by the Canadian Canal. On the date mentioned the lower gates of this lock, which are of timber, were

carried away by a vessel approaching them from downstream under its own steam and ramming them through a misunderstanding of signals. At the time this occurred the lock was full, one steamer being in it, and the upper gates were open to admit another vessel which was then entering the lock. The lower gates, when struck, were forced open and connection was thus established between the upper and lower level, the upper gates being wrecked by the force of the water rushing through. Three vessels were swept down through the lock and injured more or less seriously. The movable dam above the lock was closed by hand, and the flow of water through the Canal was shut off on June 13th.

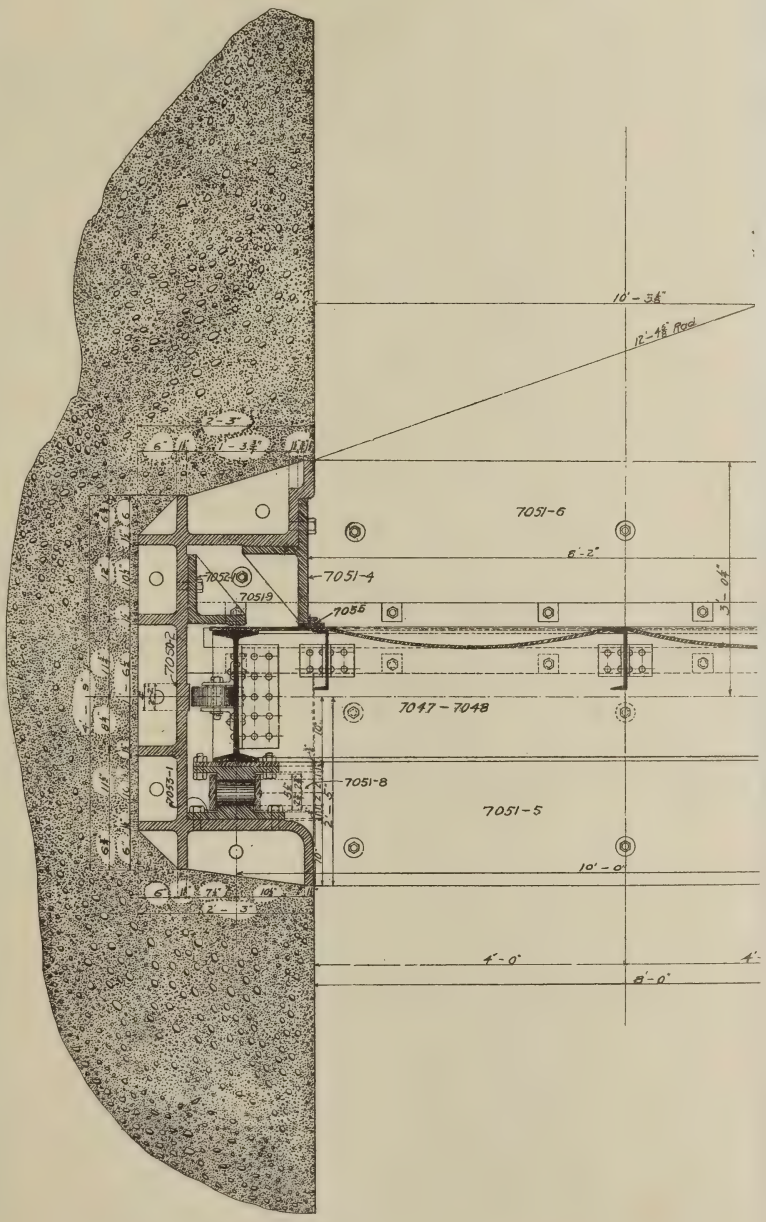
While this accident is serious, it should be considered in connection with the fact that the canal at the Sault has been in existence for more than fifty years and that this is the first incident of the kind which has occurred with anything approaching serious results.

For years past an average number of twenty thousand vessels annually have gone through the locks of the canal without material injury.

The Canadian lock has no devices to protect its gates, and while there is above the lower gates another set of gates, known as intermediate gates, this second set was not maneuvered with the lower ones, so that there was only one pair of gates opposing itself to the blow of the vessel.

While the previous record of immunity from accident shows that even in locks with unguarded gates the danger is very remote, yet this danger may be still further reduced and practically done away with by the use of duplicate gates maneuvering together at each lockage, by precautionary measures to shield the exposed pair of gates against being struck, and by providing mechanical means for bringing vessels into and out of the locks without permitting them to maneuver under their own steam. Such measures are proposed in the locks of the Isthmian Canal, which will be described later in this article, and are deemed sufficient to do away with all chance of accidents of this description.

In a recent editorial in the "Marine Review" the relative value to shipping of the lock canal and the sea-level canal is treated from the point of view of the navigator, and the conclusion reached that the sea-level canal proposed is greatly inferior to the lock canal. The article concludes as follows: "We question if a navigator can be found, who, when he fully understands both plans, will not unhesitatingly declare for the lock type, even though he may never have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12'-4⅛" Rod
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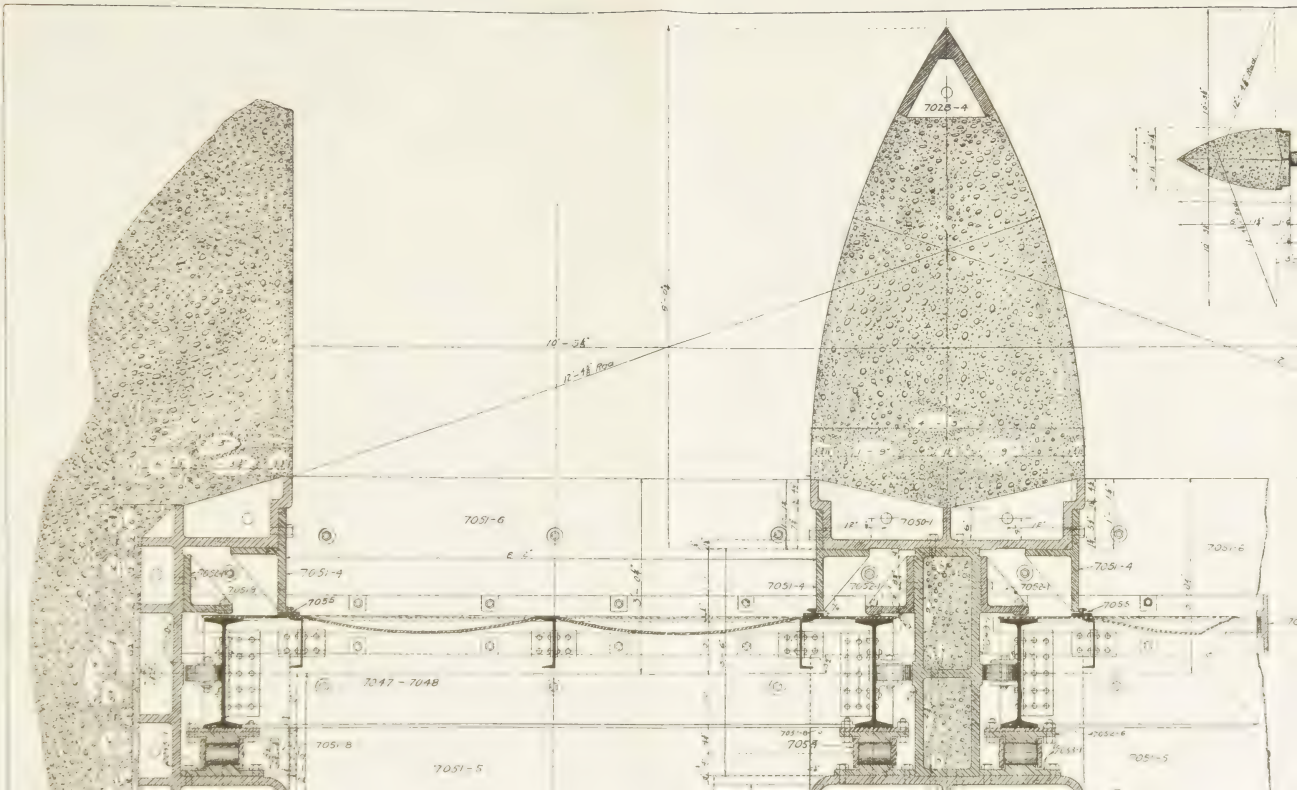
6'-2"
3'-0⅛"
7051-4
7052
7051-9
7055
7050-2
7047-7048
7051-8
7051-5
7051-1
10'-0"
4'-0"
8'-0"


7028-4
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12-1½ Rad.
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7047 - 7048
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done any locking, while, to those who have, the problem has no terrors."

The opponents to the lock canal point out as one of the great objections to this type the danger that vessels may carry away the gates of the lock and thereby effect a connection between the upper and lower levels, stating that, in such event, the whole of Gatun Lake might be emptied and navigation be suspended for an indefinite period, apart from the loss of property and life which might ensue. As an answer to this we may point to the result of experience. At Sault Ste. Marie the gates, which are unprotected, have been struck several times. On the American side the result has never been anything more than a relatively trivial damage either to the ship or to the work. On the Canadian side, as has already been described, the result of the last accident was to establish connection in the lock between the two levels. This is the result from which the opponents of the lock type predict most dire disaster, even extending so far as the obliteration of the Isthmus of Panama. The work done at the Canadian Sault even two days after the accident practically checked the flow of the water, and the situation was very soon under control.

It thus appears that in a case where this dreaded accident has happened the consequences are not nearly so formidable as had been predicted.

On the Manchester Canal, Mr. Hunter, the chief engineer, points out several accidents in which the gates have been struck and even carried away by passing vessels, but in none of those does the result seem to have been so serious as the advocates of the sea-level plan contend; nor do any appear to be such as can not be guarded against with suitable precautions in the plan and operation of the system.

One of the most prolific of the writers now furnishing the public press with criticisms of the lock canal and arguments in support of the sea-level type, has instanced two accidents in particular as evidence of the dangers in the use of a flight of locks. He has even criticised somewhat severely a member of the Isthmian Canal Commission for not having mentioned to the Congressional Committee these accidents, as instances of vessels going down through a flight of locks by crashing through the gate. One of these occurred in the Manchester Canal, when the steamer "Cassia" collided with the gates of the Irlam Lock in the summer of 1906. This, however, is far from being a case of the vessel going down through a flight of locks by crashing through the gates. To begin with, the Irlam Lock is not a flight of locks but a single lift. Further, the vessel did not enter

from the upstream side, but approached from downstream and ran into the gates. The lower gates were damaged by the shock, and the middle and upper gates by the action of the water, but the boat did not go through the lock, nor was the opening of the upper gates enough to let all the water out from the upper level. The level was subsequently drained intentionally by the engineers of the canal to facilitate repairs to the gates. The total suspension of traffic was four days, and the "Cassia" herself was not injured.

The second case to which the writer in question has reference is that of the damage to the Welland Canal, by the steamer "Nipigon," also in 1906. This again is not a case of the vessel going down through a flight of locks by crashing through the gates. On the contrary, the "Nipigon" also approached from downstream and struck and carried away the upper gates of Lock No. 16. The lower gate of No. 16 and the head gates of Lock No. 15, a short distance below, were damaged or carried away. The locks were not in flight, but were separated by a level 600 feet long. The total damage to the works was only $4,800, and the delay was only forty-two hours. In this case the upper gates are the full depth of the canal, there being no miter or breast wall to protect them against being struck by a vessel entering the lock from below.

These accidents would hardly be worth singling out for comment had they not been referred to publicly as instances of injury to a flight of locks by vessels going down through the gates. In point of fact, in neither case was a flight of locks involved, the accidents being simply instances of collisions with gates, such as are to be expected occasionally where vessels are allowed to maneuver in locks under their own steam, and where preventive devices have not been installed.

In general, the engineers who are now engaged upon the actual construction of the canal are content to attend to their work and say little, and for this reason, perhaps, most of the letters with which the public press has recently been flooded have come from those, who, for one cause or another, are opposed to the execution of the plan which Congress has ordered. Perhaps this is the reason why we have seen no reference to the dangers to navigation inherent in the passage of a narrow canal of practically one continuous series of curved lines, and for the most part with rock walls, even though that canal be without locks and at a uniform level. The sinking of a steel-hulled vessel in such a channel might mean a long suspension of navigation and certainly does mean considerable delay.

Without endeavoring to give any general statistics as to such ac-

cidents we may take again, as an illustration, navigation in the St. Marys River, which is a combination of lock navigation when passing the falls and open-river navigation below. Before the present broad and convenient channels were made in the Hay Lake and the Neebish, vessels had to use the channel of the main river, which had been improved, but was still inconvenient for navigation, the condition approximating to that of a narrow sea-level canal, with many curves, similar to that which has been taken in comparison with the present adopted lock type at Panama.

The most serious delay at the American canal at Sault Ste. Marie, due to accident at the locks, was the one alluded to above, in which one of the emptying valves broke and navigation was delayed for three days. The total time lost to vessels was four hundred and forty-eight ship-days, and the estimated cost to navigation was $56.000.

A year later, the sinking of a single vessel in the open river at St. Georges Flats, 21 miles below the lock, practically blocked navigation until a channel could be dredged around the sunken wreck, it being manifestly impossible to remove the latter within a reasonable time. The total delay in days elapsed was about twice that in the case of the lock accident. Reckoning in days' delay, it amounted to eight hundred and twenty-seven ship-days. The monetary loss to the delayed vessels was $146,000.

The result of such an accident in the narrow rocky cut of a sea-level Panama Canal where dredging around an obstacle could not be readily resorted to would unquestionably be very serious.

Similarly, the open channel of the St. Clair Flats Canal, although 300 feet wide, has not infrequently been seriously threatened and once almost stopped, all but 70 feet of the width having been blocked in the fall of 1903 by the sinking of a steamer laden with iron ore. Vessels had to be towed carefully through the narrow open space, and no draft in excess of 16 feet was permitted. Fortunately, the season of closed navigation was near at hand, and by May of the next spring the obstacle was removed. The delay and inconvenience to navigation, however, was very great, and in a narrower channel a total stoppage for a considerable time would have been inevitable. Experience of many years with the enormous commerce of the upper lakes has thus indicated that the narrow curved channel, though open, is a greater menace than the lock, as such.

In short, while we may admit that the passage of the locks requires care, yet I think it a fair statement that the danger and loss

of time in passing such a lock canal as has been ordered by Congress is much less than the corresponding inconveniences attaching to the passage of a sea-level canal such as was advocated by the majority of the Board of Consulting Engineers, or, indeed, any sea-level canal which can be built for any sum not greater than twice the cost of the lock canal.

It must be remembered that any such sea-level canal must have one lock, and will therefore not be entirely free from any inconvenience attributable to such a structure.

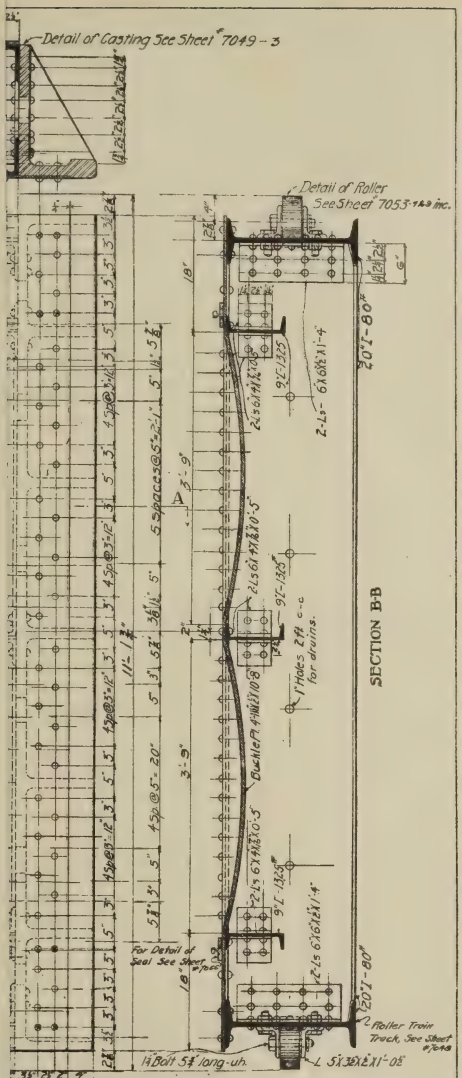
A word now as to the cost of the two types of canal. The Board of Consulting Engineers estimated the cost of the lock type of canal which it proposed at $139,705,000, and of the sea-level canal at $247,021,000, excluding the purchase price and the interest on the investment, and the cost of sanitation and civil government.

Since the time of making these estimates complete information as to the cost of doing work on the Isthmus has been gained by experience, and we now know that the cost of even such canals as the Board of Consulting Engineers projected would be much greater than they then thought probable.

In addition to this, the canal now undergoing construction differs in some particulars from that on which the minority of the Board based its estimate. This is especially the case in the locks, which have been increased to 110 feet in width and 1,000 feet in usable length; also, the narrow part of the Culebra Cut has been increased from 200 feet to 300 feet in width.

The construction cost of the adopted project when finished will be, as now estimated, $297,766,000. If to this amount be added the cost of sanitation and civil government until the end of the work, and the $50,000,000 originally paid to the French Canal Company and the Republic of Panama, the total cost, excluding interest, to the United States, of the lock type of canal now under construction, will be $375,201,000. Experience enables this estimate to be made with a reasonable degree of certainty.

Guided by the same experience, the cost of the sea-level canal of the type recommended by the majority of the Board of Consulting Engineers would be, for construction alone, $477,601,000, and the total cost, including sanitation, civil government, and the purchase price, would be $563,000,000. These estimates, however, contain more unknown factors than those for the lock canal, such as the work at Gamboa, both in the dam itself and in the diversion of the waters of the river, to permit of the construction of the dam. It


Detail of Casting See Sheet #7049 - 3
Detail of Roller See Sheet 7053-149 inc.
SECTION B-B
Roller Train Track, See Sheet #7049
For Detail of Seal See Sheet #7053
14 Bolt 5½ long-uh.
1" Holes 2½ c-c for drums.
Buckets #1021108
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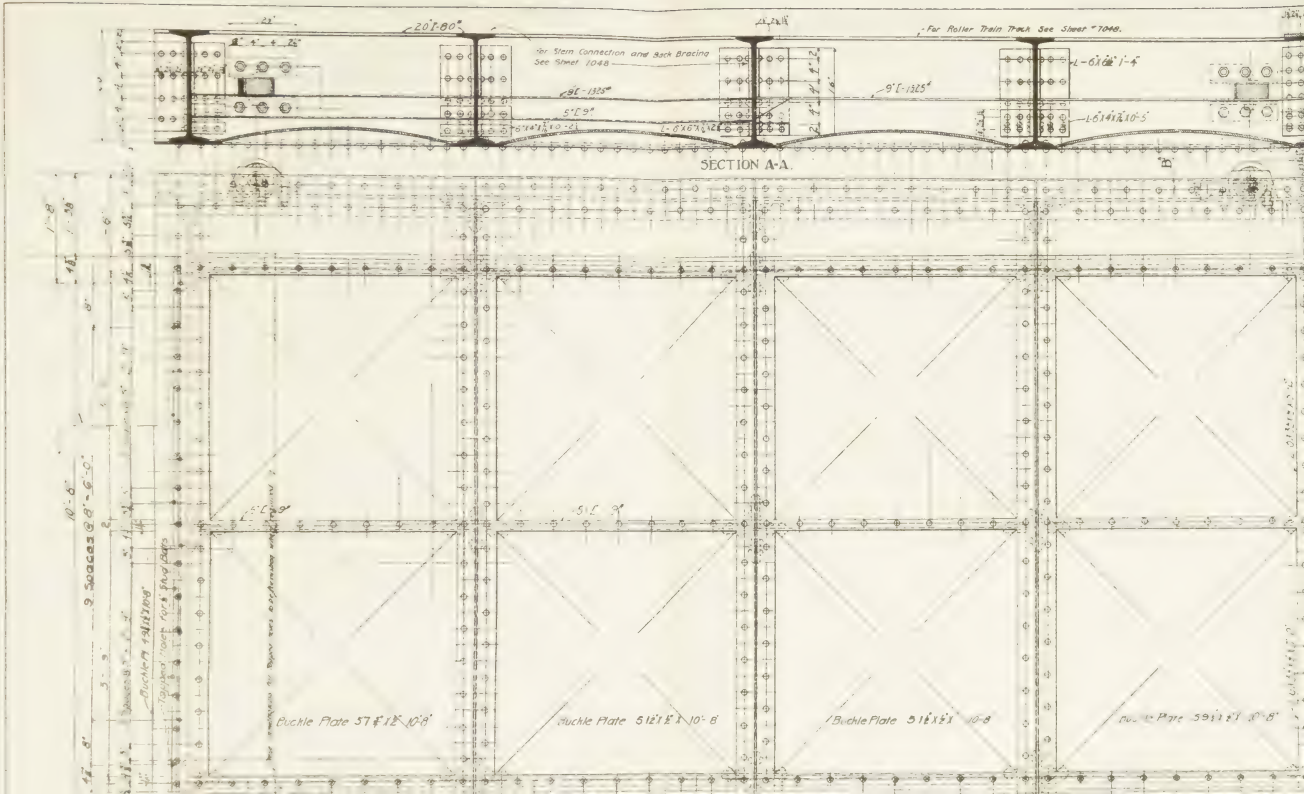
For Stem Connection and Back Bracing See Sheet 1048
For Roller Train Track See Sheet 1048.
SECTION A-A.
Buckle Plate 5/16" x 5'-1" x 10'-8"
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Buckle Plate 5/16" x 5'-1" x 10'-8"

should be remembered also that the estimate for the sea-level canal is for a narrow 150 and 200-foot channel, and that the cost of a wider and straighter channel would be very greatly increased.

Here again the advocates of the sea-level type challenge the estimates, particularly as to the unit cost, making the statement that this unit cost can be greatly reduced by the adoption of different types of machinery. One of the most widely recognized opponents of the lock type proposes a sea-level canal so large as to be unaffected by tidal currents or by the discharge of the Chagres River and other tributaries which he proposes to admit to the canal. As the discharge of the Chagres River may reach 140,000 cubic feet per second and as its bed where it joins the canal prism would be 40 or 50 feet above the water in the sea-level cut, and the surface correspondingly higher, it is apparent that at that juncture there would be an enormous volume of water cascading into the prism during floods, and that only a very large waterway could absorb such discharge without injurious currents.

As the amount of excavation involved in such a waterway is staggering, the plan can be manifestly accepted only by reduction of the unit cost. This he proposes to effect by flooding the upper levels of the prism and doing the excavation by subaqueous methods, employing rock-breaking devices to reduce the rock to a dredgable form.

As the bottom of the excavation in the summit level is now about 145 feet above sea level, or 180 feet above the bottom of the proposed sea-level canal, it is manifest that barriers must be established to hold the water in the upper levels, and that means must be provided by which the spoil can be taken through these barriers to some convenient dumping ground. Temporary locks are proposed for this purpose through which barges carrying the spoil can be taken to sea.

Experience in this country has not shown that any subaqueous method of excavating solid rock hard enough to require mining will reduce the unit cost below that of similar excavation in the dry, and in a recent large work where open competition from contractors all over the country was invited and where the rock to be excavated lay below the surface of a river carrying a large navigation, and where, further, the specifications permitted any kind of ordinary subaqueous method to be used, the contractors preferred to build cofferdams surrounding the rock and to unwater the inclosed space and excavate the rock in the dry, rather than to resort to any subaqueous method. It will be noted that this method was chosen by

men whose interest impelled them to seek the best way to do the work, and whose profit depended upon securing it.

In regard to the rock-breaking devices proposed for use in connection with this plan it should be noted that even what is claimed for them in the public prints does not indicate that, as a substitute for dry methods, their use would be economical. It is said that one of the machines could crush 15 cubic yards of rock an hour as employed at Panama. Such an output may be reasonable for subaqueous rock excavation, but why should we deliberately flood our upper levels and reduce ourselves to this output when one of our simple and reliable steam shovels will take out more than 150 cubic yards an hour as a daily average? At the rate assumed it would take ten of these rock-breaking devices, costing in all about $450,000, to crush the rock now removed by one steam shovel costing $12,000; and there would not be room enough in the canal to float the plant necessary to complete it in any reasonable time.

The cost of flooding the prism, building the temporary barriers and locks and disposing of the spoil remains also to be considered and applied to the unit cost. The engineers responsible for the work may be forgiven for doubting whether that cost would be greatly reduced, and for refusing to undertake so questionable an experiment.

The attempt to execute the project for a sea-level canal, even of small dimensions, wasted vast sums, wrecked its promoters, and brought discredit and delay upon the entire canal enterprise.

The attempt to execute the vast project of a waterway across the Isthmus which shall be large enough to absorb the tidal flow and the flood waters of the Chagres without injury is more than even the United States Government can attempt by any means now known. The means proposed by its principal advocate were considered and rejected by the Board of Consulting Engineers, even though its majority report favored a canal of the sea-level type.

I do not think that this plan will be entertained for a moment by unprejudiced engineers as against the present simple and rational methods.

Another of the most pertinacious critics of the lock canal relies for his reduction in unit cost of dry excavation upon machinery, which, so far as I know, has not yet received practical application, and must be rejected as experimental.

In the point of time of completion, the balance is emphatically in favor of the lock type of canal. The date of completion of the present plan will be fixed by the lock and dam work, rather than by the

excavation. It is now expected that the canal will be ready for use by 1915.

The time of completion of the sea-level canal would be determined either by the excavation or by the Gamboa Dam. While the excavation in the central division, which contains the Culebra Cut, has recently been going forward at a rate which exceeds the original hopes of the Commission, yet the maximum rate has probably been reached already. The total yardage taken out during the month of March last was 4,070,000 cubic yards, of which more than 2,000,000 cubic yards were from the central division; but it is the general belief on the Isthmus that these figures will never again be equalled, and that from now on the yardage of the dry excavation will show no further increase, and will soon begin to diminish. This is unavoidable sooner or later, since, as the Cut narrows toward the bottom, the amount of plant which can be used becomes more and more restricted. Were it required to carry the Cut to the depth necessary for a sea-level canal, which would be at least 80 feet below the bottom of the lock canal, the additional length of time would not be simply proportional to the yardage, but would increase much more rapidly than that quantity, owing to the continued contraction of the space and the consequent decrease in the amount of plant which could be used.

There now remain about 50,000,000 cubic yards to be taken out in the central division to complete that part of the excavation for the adopted plan. For the sea-level plan that same division would still have about 220,000,000 cubic yards. Remembering that the present rate in that division of 19,000,000 cubic yards per annum must diminish greatly in the lower levels, and that some time must be taken to revet the walls after finishing the excavation, it is evident that the old estimates of from thirteen to twenty years for completion of the sea-level canal are not far astray.

Until recently there has been no serious suggestion that the sea-level plan would not take much longer to complete than the lock canal, and even now those who make such a suggestion base their views upon the continuation, and even the increase, of the most favorable rate of excavation yet attained and upon the use of devices not yet sanctioned by experience.

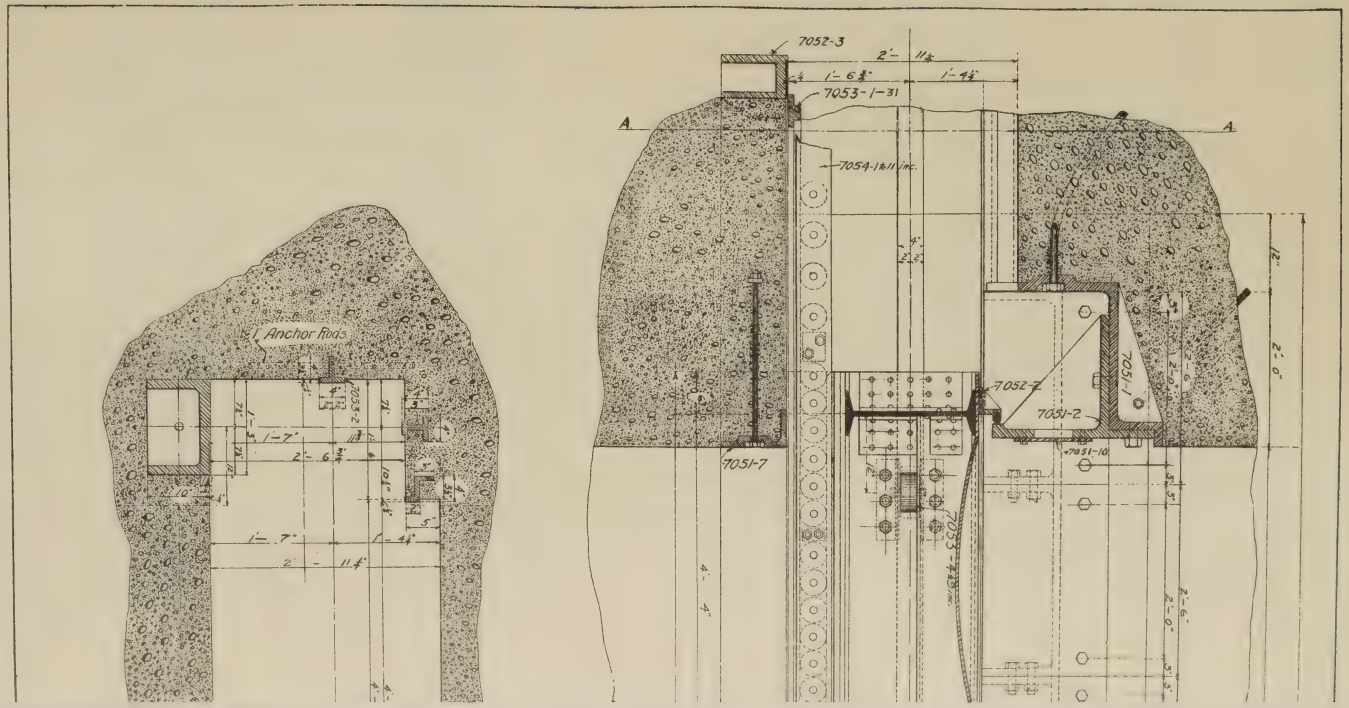
Even leaving out of consideration the unknown factor of the Gamboa Dam, and basing the estimate upon the excavation alone, it would evidently not be safe to believe that even the narrow sea-level canal, such as was contemplated by the majority of the Board of Consult-

ing Engineers, would not take at least six years longer to finish than the lock canal, and were a broader and more convenient channel to be attempted a further increase in the time would result.

The opponents of the lock plan have also laid great stress upon the rumored insecurity of the Gatun Dam and its foundation. The character of this foundation is well known, but a brief description may not be out of place. The length of the crest of the dam is about 7,000 feet, and for about 1,900 feet of this distance it overlies two gorges formerly traversed, one by the east diversion channel and the old French canal, and the other by the west diversion, now followed by the Chagres River. (See drawing.) In these gorges, underlying the surface stratum of firm red clay, there is a considerable depth of blue clay originally deposited from water, and of varying degrees of firmness. In one gorge this stratum is 200 feet thick. The character of this clay has been carefully examined both by borings to the rock and by sinking test pits, one of the latter going to the depth of 70 feet, and it is known to be impervious to water. The remainder of the dam, or nearly three-fourths of its length, rests on the hills bordering and lying between these gorges, the rock being close to the natural surface. The softer material is confined to the gorges. The crest of the dam is 35 feet above normal lake level.

The dam itself has two rock toes, or longitudinal piles of rock 1,200 feet apart, the upstream toe being raised 60 feet above sea level, and the downstream toe being 30 feet above sea level. These toes confine between them the body of the dam, the middle part of which is to be of impervious material deposited by hydraulic methods. The thickness of the impervious material is determined by the fact that at Reference 100 or 15 feet above normal lake level, it will be 100 feet thick and will then descend with the slopes shown in the drawing. These slopes are such that at the bottom of the dam, namely, at sea level, the thickness of the impermeable core is about 860 feet. Outside of this impermeable material the body of the dam will consist of any spoil which can be put in place with the least expense, while outside the toes of the dam are waste piles for the spoil of the neighboring excavation, these piles sloping down gradually and extending indefinitely, or so far as the waste material holds out. The total thickness between the outer edges of these waste piles may be 2,000 feet or more.

Last November, while the south toe was under construction, a slip occurred, by which the northern slope of the rock pile, which had been carried considerably above the fill on the outside, sank down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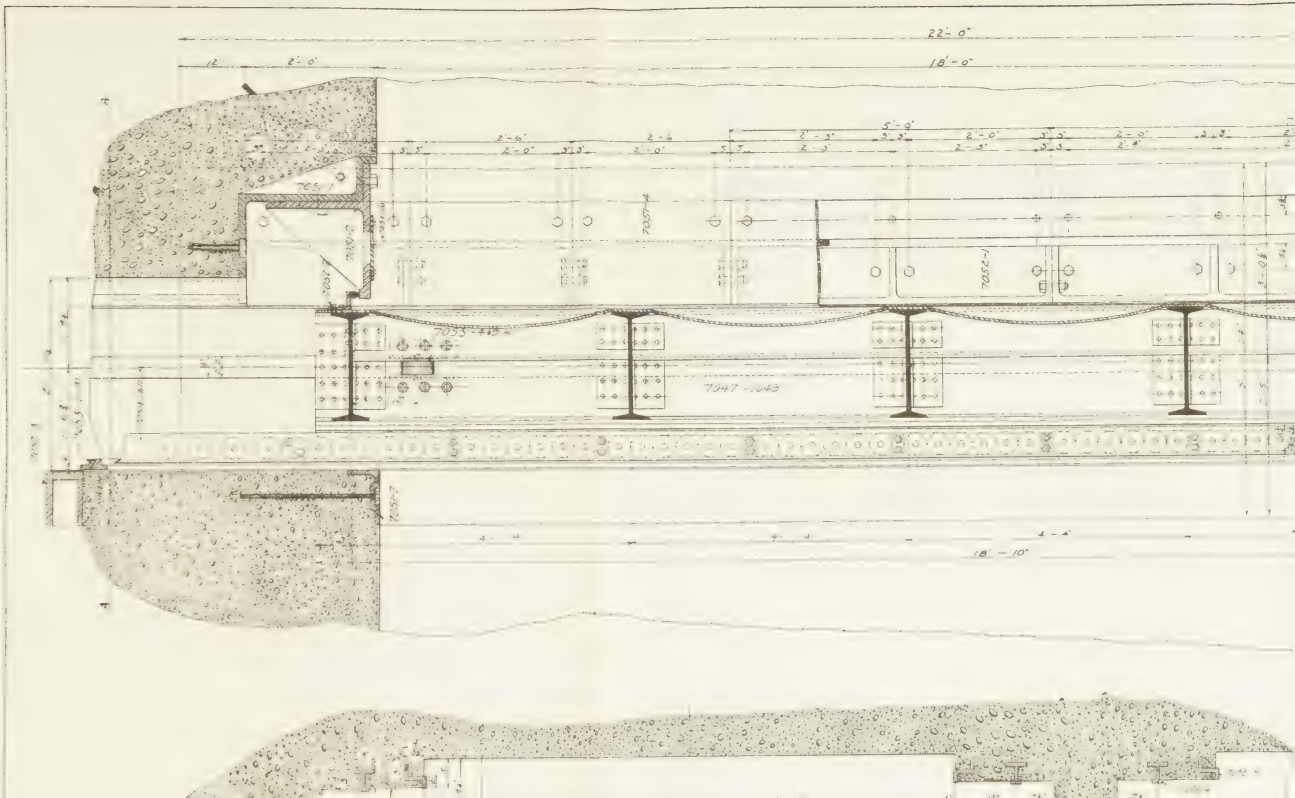

22'-0"
18'-0"
2'-0"
18'-10"

and pushed out horizontally to the north. The slip occurred at the point where the pile crosses the old French canal, and at a time when the water of the canal had just been pumped out, although the silt in the bed had not yet been removed. The crest of the rock pile dropped some 20 feet for about 200 feet of its length. In sinking, it pushed up the silt and the upper layer of the underlying clay outside of its own base toward the north in a manner with which nearly every engineer is familiar. The bank on the south side of the rock pile was entirely undisturbed, no movement taking place except on the north side where the counterbalancing weight of the water in the French canal had been removed. Several other slips had occurred near this point, but this was the largest and was immediately seized upon by a newspaper correspondent who was anxious for a sensation. It happened to occur just at the time when there was a heavy flood in the Chagres River, and the correspondent attributed the flood to the dropping of the dam into a subterranean lake. In point of fact, the slip was of importance only locally and was easily made good. It caused the engineering force on the Isthmus no anxiety whatever, and should have received little attention anywhere.

In addition to the large dam at Gatun, which supports the waters of the lake at the northern extremity, the lock-canal project presents two other small dams at Pedro Miguel and Miraflores, one with a lift of 30 and the other with a lift of 55 feet. These dams will also be of earth, but much smaller in their dimensions than the Gatun Dam. I have heard no reference to them as dangers in the lock-canal project.

As against these three dams, the sea-level project proposes five; the main one, which may be compared to the Gatun Dam in its relative importance being located at Gamboa and serving to hold back the Chagres River, the waters of which are to be admitted to the canal through sluices in volume not to exceed 15,000 feet per second, giving a maximum current in the canal of 2.6 miles per hour.

At Gamboa the site of the dam shows material more gravelly than that found at Gatun and distinctly permeable to water; consequently the dam proposed would be carried to the rock, and would be of concrete 180 feet high. During construction the river would have to be diverted and excluded. The difficulties in the way of construction can not be known in advance, but are evidently greater than in the case of the Gatun Dam, while the failure of the completed structure would entail upon the canal consequences fully as disastrous as would the failure of the Gatun Dam.

It must be remembered that Gatun was considered as the site for

a dam even by the majority of the Board of Consulting Engineers, which recommended the sea-level plan; that the site and plans have since been made the subject of examination, not only by those charged with the construction of the work, but also by consulting engineers whose names are at the front of their profession in the United States; that only recently, and since the slip occurred to which reference has been made, a board of most eminent consulting engineers has visited the Isthmus and has paid special attention to the dam, giving it, as the result of their investigations, a clean bill of health. With these endorsements from well-known professional men, I think we are justified in disregarding the evil prognostications of newspaper critics who have no share in the responsibility for the work.

One of the features of the Gatun Dam which must not be overlooked is the means provided for carrying away the discharge of the Chagres River when the latter is in flood.

The great reservoir formed by the lake is capable of absorbing a large part of the ordinary discharge of the river during the wet season and storing it for use in lockages during the dry season. The variation in the level of the lake available for this purpose is about 5 feet; that is, from Reference 82 to 87. Above Reference 87 it is not designed to allow the water of the lake to rise, the reference of the lock walls being 92 or 5 feet above the highest lake level. To prevent its rising, an escape weir is provided, located in a natural hill where the rock comes close to the surface. A channel has been excavated through the rock, and it is designed to construct across this channel a concrete dam, with its crest 16 feet below the normal lake level of 85 feet and having at its top lifting gates of the Stoney type, which, when lowered, form effective dams against the water, and when raised permit the water to flow out under the lower edge of the gates and over the crest of the dam. An area will be provided to discharge a total flow of 140,000 cubic feet per second over the crest of the spillway dam, and lower-level sluices will also be provided to regulate the level of the lake before it reaches the crest of the dam.

As the maximum known discharge of the Chagres is less than the amount which can pass the spillway, all danger of flooding the locks through sudden rises of the river is done away with.

It may be stated, also, that there has never been any flood in the Chagres River which would have a sudden effect on the enormous reservoir provided by the lake with its area of 164 square miles. It would take forty-eight hours, even with an extreme flood, to affect

this level by 4 feet, even were there no water escaping through the spillway during that time.

The channel excavated for the spillway is already being lined with concrete at a low level, and it is intended at the close of the next dry season to dam off the present outlet of the Chagres River and force its waters through the spillway while the dam is under construction.

When the earth dam nears completion the spillway dam will be hurried forward during some favorable dry season.

There will be no danger incident to this construction even were no low-level sluices provided, since it will take months for the water to accumulate in the lake, and the concrete work can readily be kept ahead of the slowly rising surface. To provide, however, against any unforeseen delay, low-level culverts will be constructed in the dam, and with these and the lock culverts the lake level can be drawn down at any time, if desired.

It was the opinion of the old Isthmian Canal Commission, and it is the opinion of the present one, that the lock canal which has been ordered by Congress is superior to the sea-level plan, giving due weight to all the elements of suitability, cost, and time of completion. The work on this plan has now reached such a stage that to revert to the sea-level canal would mean a waste of many millions of dollars. Within six months this sum will have greatly increased. Opposition to the type of canal ordered by Congress, with whatever motive it may be urged, is in practical effect opposition to the construction of any canal at all, for, in view of the enormously increased expenditure necessary for a convenient sea-level canal, the abandonment of the lock-canal project would undoubtedly mean the abandonment of the canal altogether.

The Gatun Dam, which has just been described, occasions a difference in level between the navigable waters above and below, amounting to 85 feet at normal lake level. At this level the lake covers an area of 164 square miles. This difference in level is overcome by a flight of three locks. These locks are to be of concrete, reinforced only in a few places, and dependent in general upon their mass for stability.

The excavation for the upper lock is practically complete, and within a few weeks the operation of concrete placing and mixing will begin. On the western slope the work has progressed to about the same extent as it has on the eastern slope. The excavation for the lock at Pedro Miguel is practically finished and concrete laying will begin there within the next few weeks. The construction of the

dams there and at Miraflores has made reasonable progress, and the excavation for the locks at Miraflores is as far under way as it is desirable to have it now. On this slope the work will begin first at Pedro Miguel and, to avoid duplication of plant, the Miraflores work will follow in due course after that at Pedro Miguel.

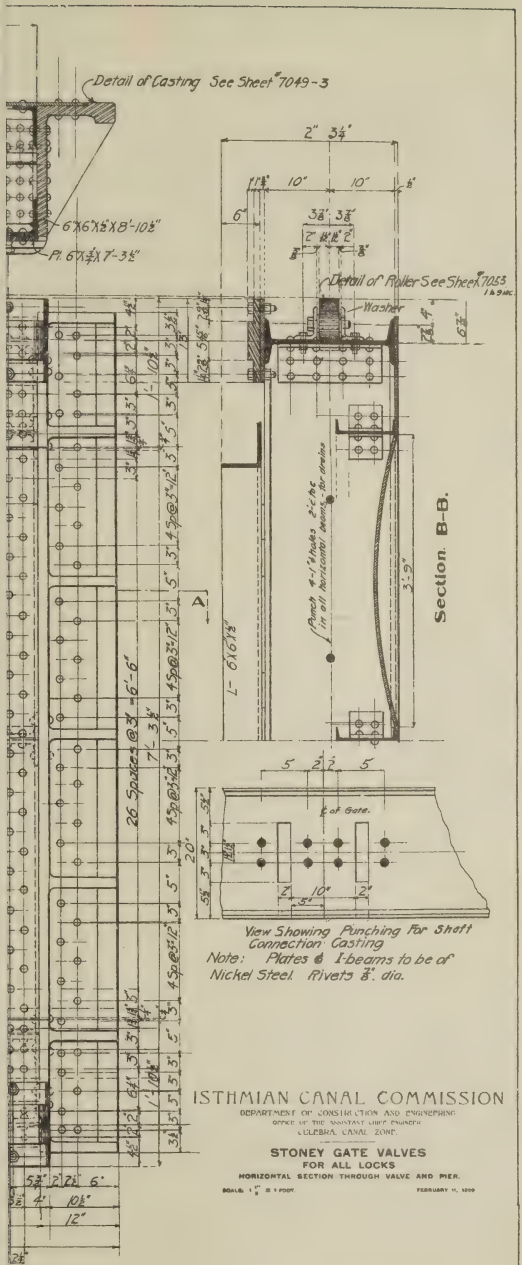
As Pedro Miguel is one terminus of the Gatun Lake, there is no necessity for a spillway at this point, since the lake level is regulated by the large spillway works at Gatun. At Miraflores, however, a spillway is necessary to control the level in the Miraflores Lake and especially to avoid trouble in case for any reason there should be a rush of water from the upper level through the Pedro Miguel locks and into the lake below. A spillway is, therefore, proposed for the Miraflores Dam, with capacity sufficient to discharge any possible outflow from the upper level above. The flood discharge of the tributaries of Miraflores Lake is insignificant and could be cared for with little difficulty.

The plans for the upper chamber at Gatun are complete, as well as for the single lift at Pedro Miguel on the Pacific slope, and advertisements for the fixed iron work and subsidiary valves have already been made public, and it is expected to open bids for these items on the 29th of June. It is of interest to note that while these items are only for the subsidiary valves and the ordinarily insignificant parts which go into the anchorage and sills for the gates, yet the total consideration of the contract will probably amount to about $700,000.

The drawing shows a general plan of the upper lock at Gatun, which may be taken as typical of all the others.

In the locks of the Isthmian Canal the chambers are by far the largest which have ever been designed. The locks are what are known as twin locks— that is, they are divided into two chambers by a central wall, thus permitting two routes for vessels, and leaving one practicable in case the other is for any reason out of commission. Each one of these chambers is 1,000 feet in usable length and 110 feet wide.

The upper locks are provided with double gates at the head and foot of the lock and with intermediate gates. The available length, measured from the protective chain to the lower pair of the upper gates is about 900 feet, and from the protective chain to the curve of the miter sill of the upper pair of upper gates is 1,000 feet. The sill of the lower pair of the upper gates is placed at the floor level, so that if a vessel of 1,000 feet is to be locked down the lower pair is left open.


Detail of Casting See Sheet 7049-3
6"X6"X⅝"X8'-10½"
Pl. 6"X⅝"X7'-3½"
Detail of Roller See Sheet 7053
Washer
Section B-B.
Punch 4-1" Holes 2'-0" c/c in all horizontal beams for strains
L- 6"X6"X⅝"
26 Spaces @ 3" = 6'-6"
View Showing Punching For Shaft Connection Casting.
Note: Plates & I-beams to be of Nickel Steel. Rivets ⅞" dia.

ISTHMIAN CANAL COMMISSION

DEPARTMENT OF CONSTRUCTION AND ENGINEERING
OFFICE OF THE ASSISTANT CHIEF ENGINEER
CULEBRA, CANAL ZONE.

**STONEY GATE VALVES**
**FOR ALL LOCKS**

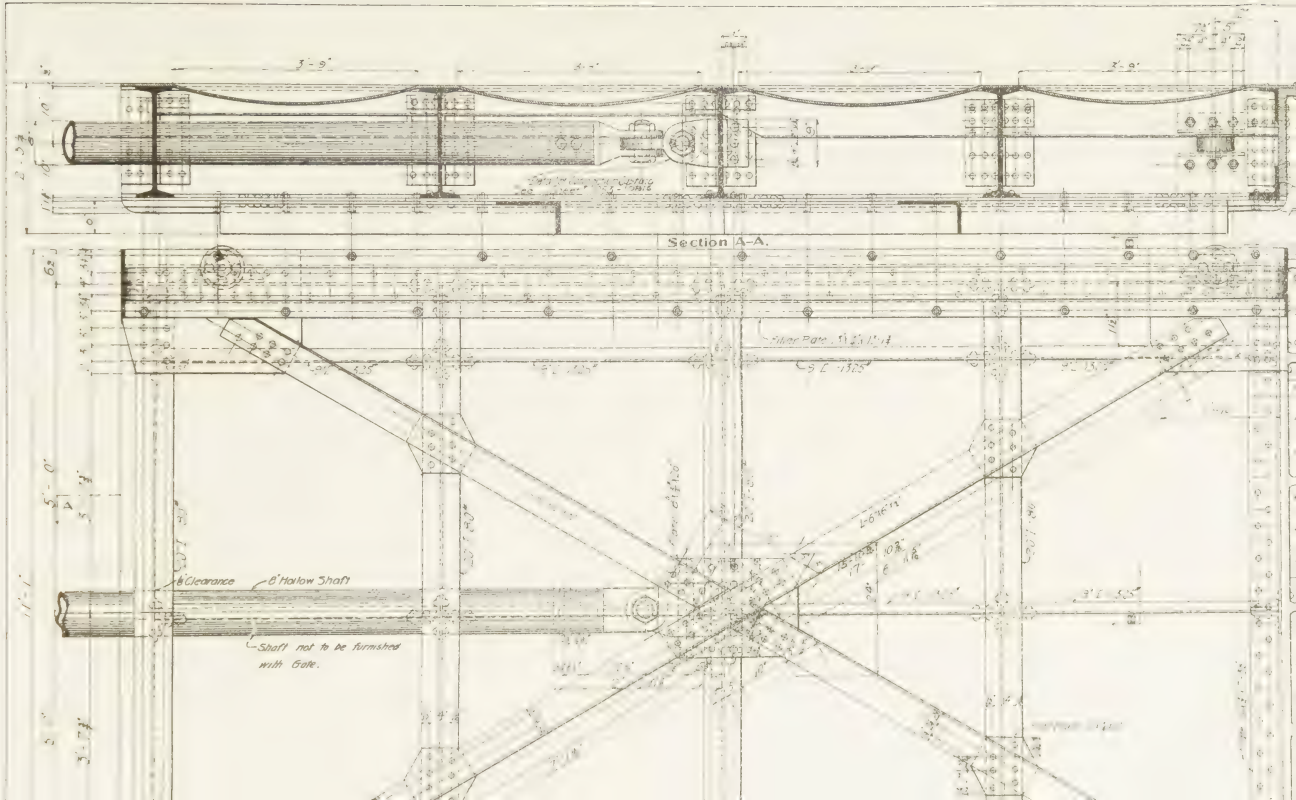
HORIZONTAL SECTION THROUGH VALVE AND PIER.

SCALE 1" = 1 FOOT. FEBRUARY 11, 1909

7048

G-24
P-17
M-12

THE NORRIS PETERS CO., WASHINGTON, D. C.


Section A-A.
6' Clearance
6' Hollow Shaft
Shaft not to be furnished with Gate.

The middle gates divide the lock into two parts, one of which is 550 feet long, measured from the lower protective chain, and the other 350 feet long, measured from the upper protective chain. Either one of these chambers may be used singly or both may be combined. It is therefore possible to lock vessels up to 550 feet in length without the expenditure of water necessary in using the entire 1,000-foot lock chamber. In fact, we have really four locks, 350 feet, 550 feet, 900 feet, and 1,000 feet in length, and our water supply can be correspondingly economized.

About 95 per cent of all the vessels afloat can, if necessary, be passed through the 550-foot lock, but in estimating on the water supply we consider that 15 per cent of the vessels passing will require the use of the largest locks.

Allusion has already been made to protective devices used to safeguard the gates in the locks. One of the devices now in view for the Panama Canal is a chain placed above the gates, in the upper locks, and below the lower gates in the lower locks.

This type of protection has been applied at harbor locks in Great Britain, and is very simple in principle. When in use, the chain is stretched across the lock near the surface of the water and is passed around fixed capstans on the walls. Reliance is placed upon the friction of the chain around these capstans to check the way of a vessel which may strike it. Instead of the frictional resistance of the chain around the capstan barrel, resistance may be provided by friction brakes, or by hydraulic cylinders, and a force may be developed, which, acting over the distance between the chain and the gates, and increasing continually as the vessel moves downstream, is sufficient to arrest a large vessel at considerable speed before the gates can be struck.

A similar chain is placed above the middle gates and, as the device is not very expensive, it may be adopted elsewhere in the system. When not in use, the chain lies in a groove in the lock floor and vessels pass directly over it.

It is manifest that the accidents which are most to be feared are those which result from collision with one pair of gates when the other pair is open. Such an accident might result in opening connection between the levels through the lock chamber. For this reason double gates will be used and the protective chain will be placed at vulnerable points, but precaution has not ceased with these devices. Should the accident in question occur and should connection be opened through the lock chamber before the upper gates are

closed, it is apparent that a current would be set up through the chamber and that it might be impracticable to close the upper gates with safety. To guard against this chance a dam of the movable type has been placed in the head bay, above the upper gates. This dam consists essentially of a swing drawbridge from which wicket girders can be lowered, one at a time, the upper ends being supported by the strong horizontal truss work of the bridge, and the lower end by a sill provided in the bottom of the forebay.

The wicket girders, exposing but little surface to the water, can be lowered without difficulty, and when lowered afford runways for rolling paddles or gates of the Boulé type, which can be let down one at a time, closing the spaces between the wicket girders.

These gates, as they are lowered in horizontal tiers, will form submerged weirs or dams building from the bottom of the waterway upward, thus simultaneously decreasing both the area of the waterway and the head of the stream. The dam is quite similar to the one which is to be built at Sault Ste. Marie, and resembles also in its general features one which was in use there for many years, but was dismantled after the widening of the canal threw it out of use.

In addition to the precautions already mentioned of duplicate gates, cable protection and movable emergency dams, a further safeguard is proposed to minimize the chance of accident in the locks. It is to be observed that practically all of the accidents in the locks of which we have record in recent years have happened through some error in the maneuvering of a vessel entering or approaching the lock under its own steam. To obviate this danger the Commission now has under consideration the installation of powerful appliances on the lock walls to bring vessels in and out of the locks, thus obviating all use of the vessel's motive power and the danger of false movements through misunderstanding of signals or otherwise.

The main culverts through which the lock chambers are filled are located in the walls, and connect with the chamber through lateral culverts opening upward through the lock floor. This system is adopted in order to distribute the water as evenly as possible over the entire horizontal area of the lock, and to reduce the disturbance in the chamber when the latter is filled or emptied quickly.

The main culverts are each 254 square feet in area, or the equivalent of a circle 18 feet in diameter. They are controlled by valves of the Stoney type—that is, gate valves moving on frames of live rollers, thus doing away with the friction to a large extent.

It must be remembered that most of the valves must maneuver

habitually under a head of 60 feet, and must remain tight under a head of 80 feet. It would manifestly be difficult to operate under such heads a valve large enough to close the entire culvert of 254 square feet, and for that reason the culvert is divided at the valves into two parts by a central pier, and each of the halves is controlled by a single valve. Each one of these valves is 200 feet square in area over all, and the waterway which it closes is 8 feet wide by 18 feet high. The side wall culverts connect with the lock chamber directly through the lateral culverts. In the middle wall, however, the main culvert connects with each of the twin lock chambers on its two sides, and, to preserve the separation of these chambers, each of the lateral culverts has to be closed at its junction with the main culvert by a subsidiary valve. These valves are of the cylindrical type. It will therefore be possible to fill either lock chamber through the side culverts alone, through the middle culvert alone, or through both. If both culverts should be turned on at full speed at once, without regard to the rate of filling, the 1,000-foot lock chamber could be filled in between eight and nine minutes. As the lift is 30 feet, the rise or fall of the vessel within the lock at this rate of filling would be uncomfortably rapid. It is not believed that in the ordinary operation of the lock vessels will desire that it should be filled or emptied in less than about fifteen minutes, and the side wall culvert alone is sufficient for this.

In the operation of the lock it is contemplated that the one side wall culvert will be used for the ordinary lockages in the 550-foot length and the 350-foot length, and that the middle wall culvert will be called into play only when the largest locks are used to accommodate one very large vessel or a number of small ones simultaneously.

The gates closing the locks are of the ordinary mitering pattern and are made of steel. They will be the largest of their type in existence, but others of a comparable size are in successful operation. For example, the largest gate on the Isthmian Canal will be 82 feet high, and will close an opening of 110 feet; while the largest gate now in existence in the United States is 43 feet high and closes an opening of 100 feet. At the Cascade locks, however, the gate is 55 feet high, although the opening which it closes is only 90 feet wide.

It will be remembered that each gate is made up of two leaves. There will be from eighty-four to ninety-six such leaves in the locks, the exact number depending upon whether intermediate gates are used in the lower locks. Each of these larger leaves will weigh 550

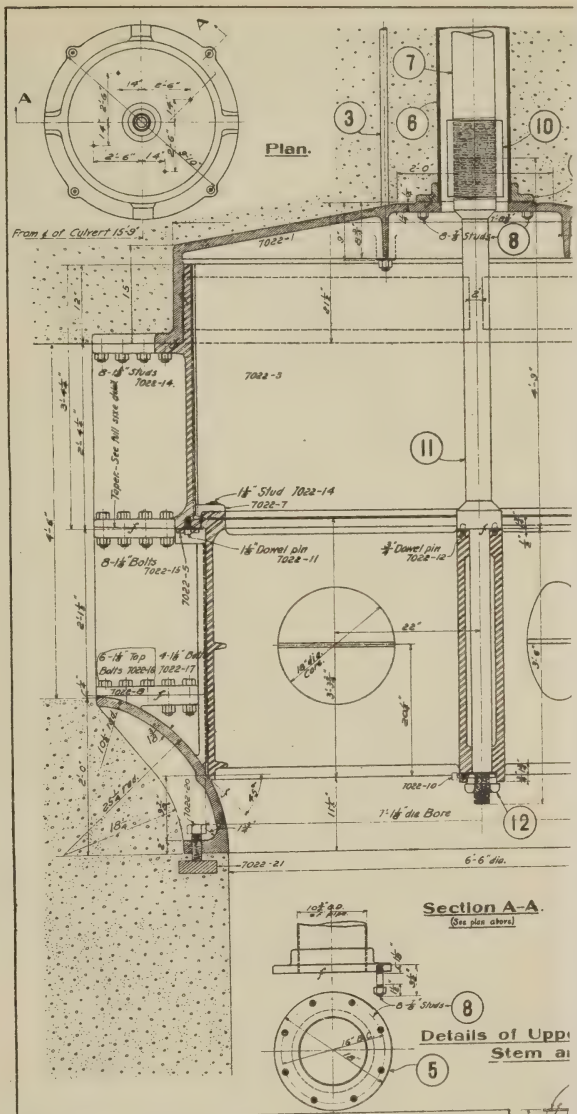
tons. If all of the gate leaves on the canal could be piled on top of each other they would form a tower more than a mile and a quarter high, and the total weight would be near 50,000 tons.

It is intended to operate all the gates and valves electrically, the power being obtained eventually from the head created by the Gatun and Miraflores dams. Pending the construction of these dams, however, batteries of boilers are being installed in the power houses to operate the generators and supply power during construction.

Question has been raised in regard to the adequacy of the water supply to maintain a large commerce through the locks. This point has been under investigation for many years, and data bearing upon it have been collected and studied with the greatest care.

It is known that during eight or nine months of the year plentiful rainfall is available, whereas during the remaining four or three months there is practically none, and it becomes therefore a question of storing during the rainy season a sufficient supply to last during the dry season. The enormous reservoir capacity of Gatun Lake is available for this purpose. With the bottom of the canal excavation in the summit level placed as it is at 40 feet above the sea level, it is evident that navigation, with the extreme depth desired of 40 feet in salt water, can be carried on until the surface of the lake falls to the Reference $+81-\frac{2}{3}$. As it is intended to allow the water to rise up to Reference $+$ 87, there is a little more than five feet of storage available. With this amount of storage, and making due allowance for power consumption, evaporation, seepage and leakage at the gates, we find that during a dry season of minimum recorded flow, assumed to coincide with the wet season of minimum flow, an average of forty-one passages of the canal per day would be possible, and that in the average dry season the daily number of fifty-eight double lockages is possible—that is, fifty-eight complete transits of the canal. Such a number is more than the twenty-four hours of the day would permit, allowing vessels to follow each other at intervals of one hour, and we may safely say that the water supply is considerably in excess of any demands which can be made upon it. The limit is, of course, only imposed for the dry months. During the rainy months there is practically no limit except that of time.

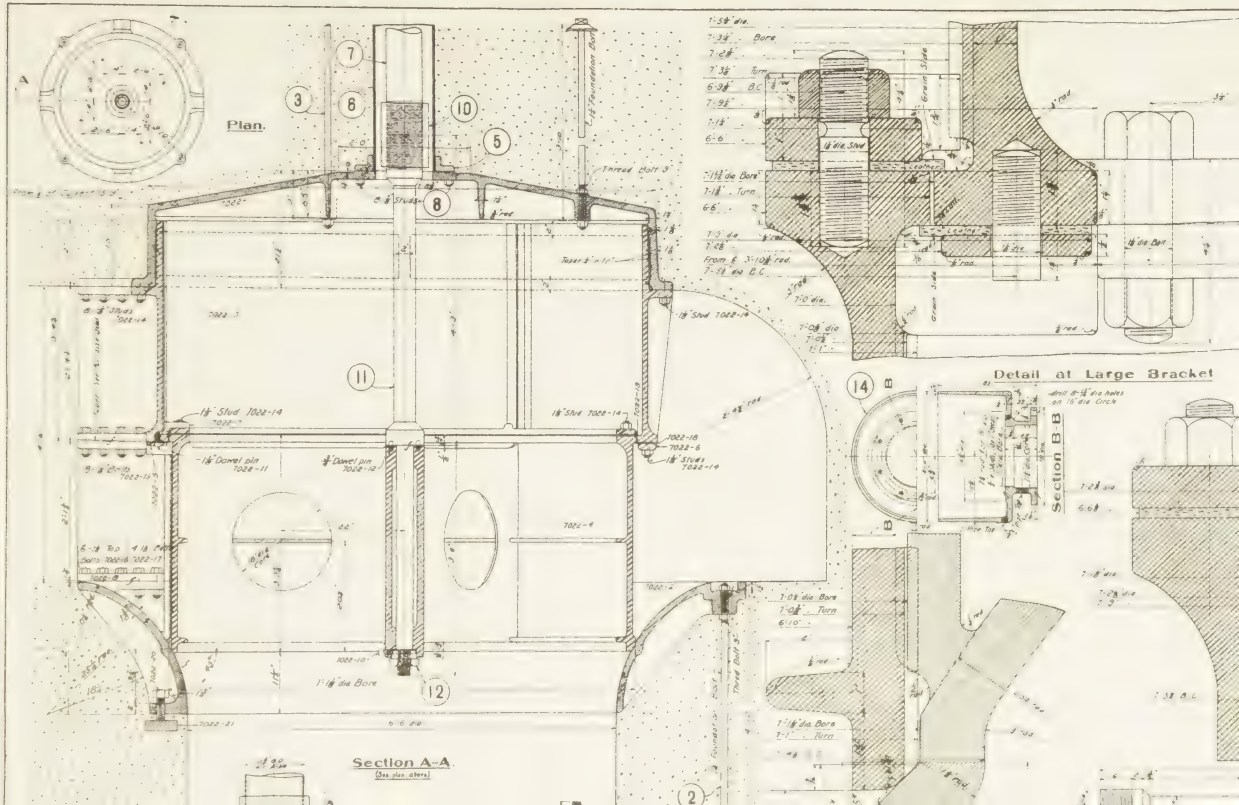
With the design adopted for the locks a certain amount of water can be saved at each lockage at Gatun or Miraflores whenever a vessel does not draw the full permissible depth of 40 feet, as will be the case in ninety lockages out of one hundred. This saving can be ef-




Bill of Material for one 18" Cylindrical Valve

| Piece Nº | Pieces Req'd | Material | Description | Weight | Remarks |
|---|---|---|---|---|---|
| 1 | 8 | Cast Iron | Washer 6" O.D. 1" high | 46 | Standard |
| 2 | 4 | Steel | 1¼" Sqhd. Bolt 3'-0" Long | 92 | Hex Nut. |
| 3 | 4 | " | " " " 4'-0" | 76 | |
| 4 | 11 | Galvanized Cast Iron | Shrunk on Flange of 10" O.D. Pipe | 638 | Drilled Standard |
| 5 | 1 | " " | " " " " | 58 | Tapped Special. |
| 6 | 6 | Iron" Steel | Lap welded pipe 10¾" OD.-7-11⅜ Tgths. | 330 | |
| 7 | 3 | Galvanized Steel | Extra Strong " 6" I.D.-16" " | 1370 | Ends Threaded. |
| 8 | 8 | Steel | Stud Bolts ⅞" x 3½" Long-Hex. Nut. | 7 | |
| 9 | 40 | " | Bolts " " " -Hex. H'd N. | 48 | |
| 10 | 3 | Galvanized Steel | Sleeve coupling for Piece Nº 7 | 1345 | Extra Strong |
| 11 | 1 | Forged | Valve Stem | 363 | |
| 12 | 1 | Steel | Lock Nut | 16 | |
| 13 | 1 | Cast Steel | Pilot Nut | 34 | |
| 14 | 1 | Cast Iron | Coupling for Shifting Box. | 330 | |

Note:- For Operating Mechanism Details see Drawr. Nº 7022
Valve " " " Nº 7022


Plan.
Section A-A
(See plan above)
Detail at Large Bracket
Section B-B
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fected by cross filling or emptying through the middle wall into the other twin lock chamber.

On the whole, it is safe to count upon water for as many lockages as the time in the day will permit.

The traffic of the Suez Canal now amounts to about 21,000,000 gross tons per year, carried by about twelve passages per day. The commerce of the American Canal at Sault Ste. Marie, which, with its two locks side by side, offers the same facilities as do the twin locks of the Panama Canal, amounts to, say, 40,000,000 tons of freight annually, and is carried on an average of about thirty-five lockages per day during the season of navigation, or twenty-four lockages per day during the calendar year.

It is often assumed that the construction of the lock canal limits navigation forever to the facilities provided by that canal as originally constructed. This is not at all the case. Other locks can be built paralleling those now to be built and tributary to the same trunk canal, as has been done at Sault Ste. Marie, and a dam may be built at Alhajuela to provide additional water supply for these new locks.

The situation is then this: The canal which is now proposed, with its type of locks devised to economize water, will provide, as shown, for as many lockages as the twenty-four hours of the day will permit, namely, forty-eight complete passages of the Isthmus daily. Such a number of lockages on the basis of carriage now in existence at St. Marys River, will accommodate 80,000,000 tons per annum. A commerce of this magnitude is many, many years in the future, and, if we give present facilities for it, it will only be in the time of our far distant posterity that these facilities will need increase. We may safely leave to that posterity the chance to spend some of its own money in meeting the need, should it ever arise. Why, then, should we burden the nation at the first execution of the project with enormous unnecessary additional cost, and still more enormous interest charges, by attempting to provide in advance, whether by the construction of the Straits of Panama or otherwise, for this remote contingency?

There has been some allusion in the public print to the danger from earthquakes in the Canal Zone. I am unable to promise that they will not occur, but we have very direct and striking evidence that none has occurred with any degree of severity for the last two hundred years. There are ruins of that age now standing in New Panama, as well as in Old Panama, which would unquestionably have fallen under a shock of any magnitude.

If we are to have a canal of any practicable description across the Isthmus we must take the chance of earthquakes, for they might destroy the dams and tidal lock of a sea-level canal as well as the structures belonging to the approved type. It may be stated that it would take a considerable jar to affect injuriously any of these structures.

We do not need to discuss at length the vulnerability of the lock canal in time of war, although its alleged weakness has been urged as an objection. Any canal that we can build there will be vulnerable, and if we are to hold it we must defend it and not trust to its type for its protection.

It may be interesting to glance now at the means which are used in carrying out the work. Broken stone for the concrete comes from quarries at Porto Bello on the Atlantic Coast and at Ancon Hill for the Pacific Coast work, the sand being brought by water from the nearest place on the coast where it can be provided. A mixing plant of the cubical type, capable of mixing 2,000 yards of concrete per day, is to be installed on each slope, and the material will be handled at Gatun by a cableway and on the Pacific Coast works by traveling cranes.

The subaqueous excavation is performed by dredges, the channels in the harbor being excavated by sea-going suction dredges of the type which the United States Government has used so freely on the seacoasts and on the Great Lakes.

These steamers draw up the sand by centrifugal pumps through pipes terminating at the bottom in a heavy suction head, and discharge it into bins in their own hulls. When these bins have been filled with spoil, the boats steam away to the dumping grounds, empty them, and return for another load. There are two of these sea-going suction dredges—one at each terminus of the canal—and each can be relied upon for about 250,000 cubic yards per month all the year round.

There are seven ladder dredges used, which have been rebuilt from old French material. These dredges are very useful, and one of them has made a record of 140,000 cubic yards per month. There are also dipper dredges with 5-yard buckets, and suction dredges which discharge the spoil through long pipes, floated where necessary on steel pontons. In addition, there is a Lobnitz rock-breaker.

At one point in the canal, namely, at the head of Limon Bay, the excavation is going on by drilling and blasting from the surface of the ground, which is only just above the water level, and subse-

quently dredging the material out and dumping the spoil from barges in the bay. This method is economical where the haul by barges is not great, and there is sufficient space for the necessary floating plant.

At other points, as, for instance, at Mindi, a short distance above, and at bends of the Chagres near Gorgona, the excavation is carried on by the dry method, although the bottom is considerably below the water level, ridges being left as dams to keep out the water.

The dry excavation is carried on almost exclusively by steam shovels. It must be remembered that the greater portion of the material to be removed, especially in the Culebra Cut, requires blasting. The sequence of work is, therefore, first, drilling, in which tripod drills are used for the shallow holes, and well drills for the deeper holes, compressed air being the usual motive power in both cases; then loading, blasting, digging, and removal of spoil.

The powder which has been used for blasting is principally saltpeter dynamite of strength varying from 30 per cent to 60 per cent of nitroglycerine, 45 per cent being the most common. Deep holes are usually first sprung with a small charge of dynamite, and then loaded with amounts reaching as high as 1,000 pounds for each hole. A varying number of holes are filled at each blast, the largest one ever fired containing about 37 tons of dynamite. The operations of the Canal require 800,000 to 1,000,000 pounds of dynamite each month of the year.

The large blasts are fired by electricity, there being two fuzes in each hole, all holes being coupled in parallel. For the first year or so of the work it was usual to couple the fuzes in series, but several misfires occurred, owing to the most sensitive fuze in the series exploding first, and cutting out the fuzes beyond it. The operation of firing in parallel has obviated this danger, and since it was adopted misfires have practically ceased.

The large blasts break up the rock into fragments, the greater part of which can be handled by the steam shovels, but it often occurs that some of the larger fragments have to be broken again after the main blast. This is done by what are known as adobe blasts—that is, small charges of a few cartridges of dynamite laid on the surface of the rock and covered with clay or mud. Such shots are usually fired by blasting fuzes instead of by electricity.

There have been several serious accidents in the blasting operations, the worst one having occurred last December, when twenty-three men were killed at Bas Obispo by a premature explosion of a blast containing 23 tons of dynamite. The last of the fifty-three

holes constituting the blast was being charged when the explosion took place. It occurred during the dinner hour, just after the morning's work had stopped, and the principal loss of life was among the laborers who were passing through the Cut, in front of the bench where the blast was fired, on their way to their quarters for dinner. Curiously enough, the men who were loading the last hole were not killed.

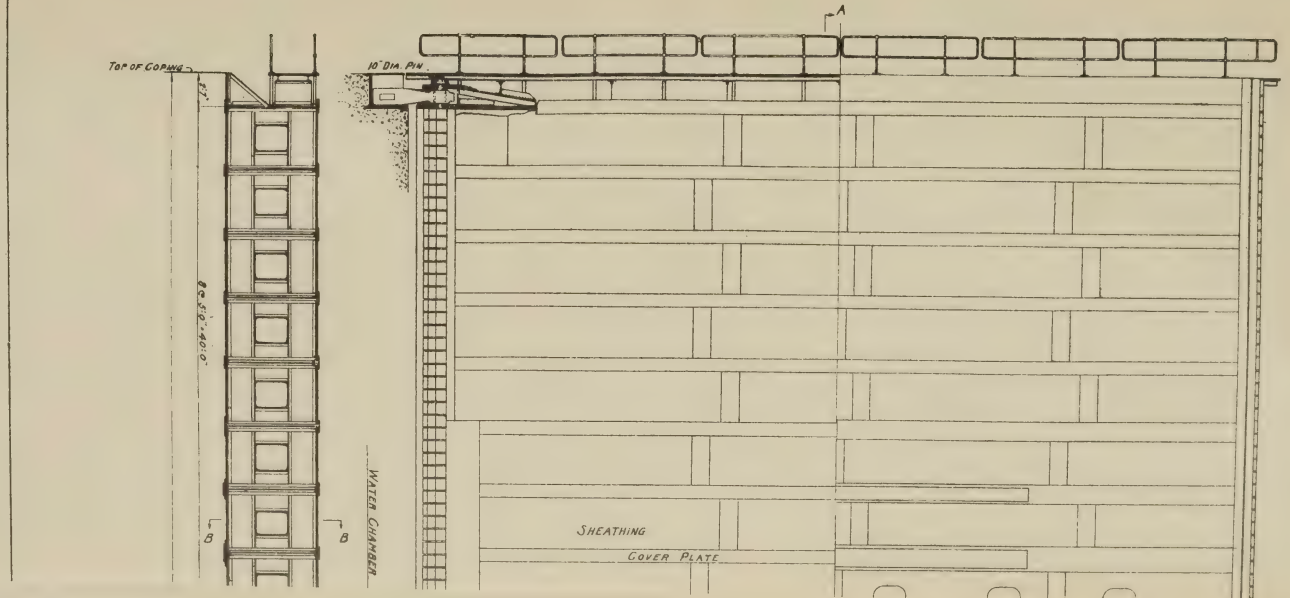
In an engineering journal some months ago the engineers on the Isthmus were criticized very severely for not using black powder instead of dynamite in the blasting operations. Experience there has shown the value of dynamite of a reasonably low grade in the work, and the black powder, which was suggested by the self-constituted critic referred to, would be of little use, since, during the greater part of the year, the holes when they are fired have from 10 to 30 feet of water in them, and have been standing thus partially filled with water for hours or days before being fired.

The removal of the spoil is the feature of the work upon which the time depends. For the level which the bottom of the Cut has now reached adequate dumping grounds can not be found in the neighborhood of the work, and the average haul of the spoil from the Cut to the dump is now about 10 miles.

The steam shovels used for the excavation are of three sizes and two makes, the largest size having buckets of 5-yard capacity; the next 2½ yards, and the smallest, 1½ yards capacity. The work of the steam shovels is very satisfactory. In the month of March fifty-seven steam shovels at work in the central division made each a daily average of 1,328 cubic yards in eight hours, accomplishing a total excavation of 2,041,000 cubic yards in the twenty-seven working days of the month.

The spoil is carried in flat cars or steel side dump cars. Each train of flat cars that goes from the Culebra Cut has seventeen loaded cars when going northward and eighteen loaded cars when going to the south dumps at La Boca or Miraflores. Each train carries about 360 cubic yards of material and the Culebra Cut puts out each day the equivalent of two hundred such trains.

There are three large dumps in operation, with smaller ones near the lock site excavations, the large dumps being located at Tabernilla, which take the spoil from the north end of the Cut, and at La Boca and Miraflores, which take the spoil from the south end. These dumps are provided with means for unloading the trains of flat cars. It would evidently take a long time to unload each of these trains.


Top of Coping
10" Dia. Pin
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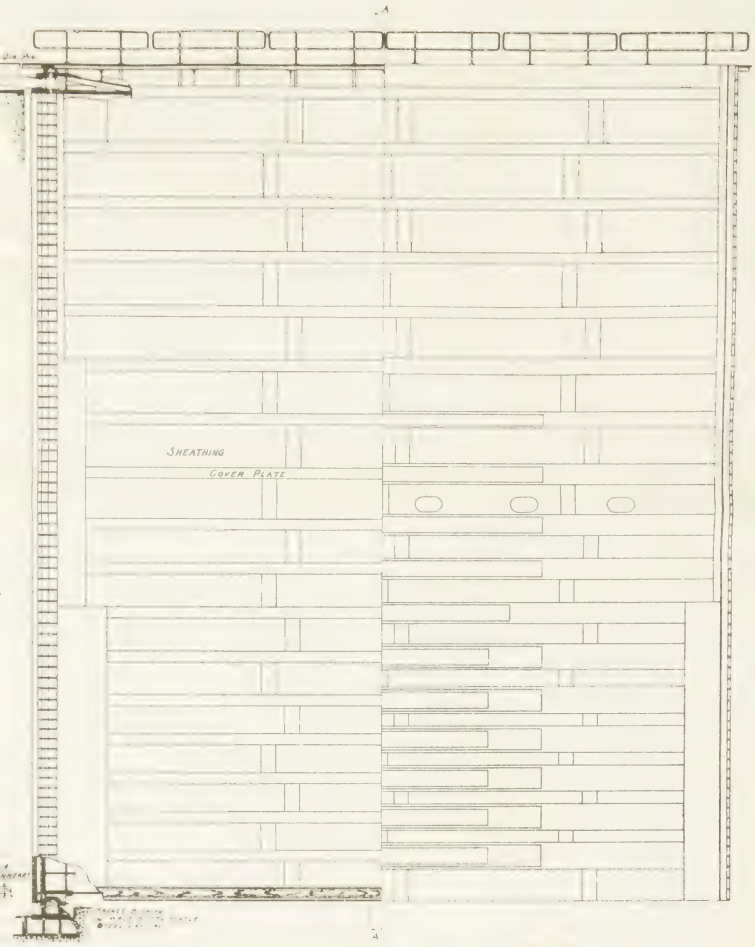
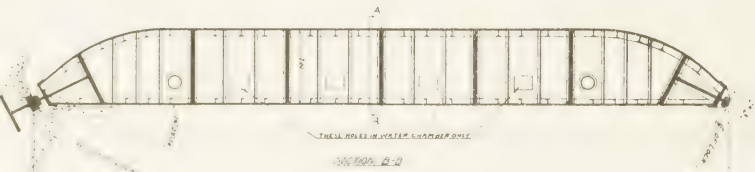



EVATION OF DOWN STREAM SIDE

ELEVATION OF UP STREAM SIDE




SECTION B-B

carrying about 360 cubic yards and with rocks sometimes weighing 8 to 14 tons, by hand. They are unloaded by a huge plow coupled on the rear end of the loaded train; on the front end is coupled a strong winch, the engines of which get their steam from the boilers of the locomotive coupled just ahead. A cable is stretched from the winch to the plow, the train moved to the dump, and the plow hauled by the cable the full length of the train, plowing off the material to one side of the track. The side dump cars are dumped by air or by hand, both patterns being in use.

It is evident that the row of material left alongside the train would eventually block the track and prevent the movement of the train, and that it is necessary to spread out this row and force it over the edge of the dump. For this purpose what are known as spreaders are employed. They are so similar to the snow plow that they need no further description.

It is also evident that after a few such operations the edge of the dump will build out so far from the track that it would not be practicable to use the dump further without moving the track closer to the edge. For this purpose a track shifter is employed, which takes up the track bodily, in sections, raises it 2 or 3 feet in the air and then moves it a few feet to the side toward the edge of the dump.

It is possible to throw the track as much as 9 feet, but the usual throw is not more than 5 or 6 feet. The machine leaves the track in such a condition that it is possible for trains to run over it at once, but it is usual to send a gang after the machine to put the finishing touches on this work.

The organization under which the work is conducted comprises a Department of Construction and Engineering, a Department of Sanitation, a Department of Civil Administration, the Quartermaster's Department, the Subsistence Department, Department of Examination of Accounts, Department of Disbursements, Purchasing Department, and Legal Department. In addition, the Panama Railroad works with the Commission's organization, though strictly speaking, a distinct corporation.

The work of the Department of Construction and Engineering is under charge of the Chief Engineer. It is divided into geographical divisions, the Pacific Division taking all the work from deep water in the Pacific to and including the Pedro Miguel Lock, except certain parts intimately connected with the Central Division. The Central Division extends from Pedro Miguel to Gatun, and includes the Culebra Cut and the greater part of the dry excavation; the Atlantic

Division extends from Gatun to deep water in Limon Bay. These divisions are each in charge of a division engineer.

There is an assistant chief engineer, charged with the preparation of the plans of the locks, dams, and regulating works; and an assistant to the chief engineer, charged with the supervision of mechanical operations, machine shops, the cost-keeping records, the preparation of estimates, and so forth.

In another branch of the Chief Engineer's Office, in charge of an assistant engineer, matters relating to general surveys, meteorology and river hydraulics are cared for. There is also a mechanical division, which has charge of the work of the machine shops and so forth.

Nearly all of the skilled mechanics on the Isthmus, in fact, practically all employees above the grade of unskilled laborers, are American citizens, and no new employees not citizens are now taken on in such capacity. Their pay is high compared with what the same work would command in the United States, and they receive, in addition, quarters, light, heat, medical attendance, and the privilege of purchasing their supplies from the commissary stores maintained by the Panama Railroad for the benefit of the Commission's work. Monthly employees also receive six weeks' leave of absence with pay annually.

For those who are unmarried or who make no arrangements for keeping house, the Commission maintains hotels where good meals can be purchased at the rate of thirty cents per meal.

The unskilled laborers, of which there are approximately 30,000, are West Indian negroes or white Europeans, principally Spaniards. No unskilled labor is brought from the United States.

The lowest pay of the negro laborer is ten cents per hour, American currency, while the contract pay for the Spanish laborer, who comes from Europe under agreement for employment, is double that sum, or twenty cents per hour.

Kitchens are maintained for the negroes at which meals can be purchased at the rate of about thirty cents per day; and for the European laborers other messes are maintained where the price is somewhat higher, or about forty cents per day.

The men are all provided with barrack accommodations, with adequate provision for shower baths.

Many of the colored laborers, however, show a disposition to establish homes for themselves where they can keep their families and do their own cooking. This tendency has some bad effects, but on

the whole is not an unmixed evil, as it results in establishing what is practically a reservoir from which a steady supply of local labor can be drawn.

For the recreation of the employees four clubhouses have been built, which are operated through the medium of the Young Men's Christian Association, the expense, of course, being borne by the Commission.

In these clubhouses billiard and pool tables, bowling alleys, reading rooms, and circulating libraries are established and assembly rooms are provided where dances can be held. These clubhouses are of the greatest possible benefit, and the number will be increased in the near future.

The sanitary conditions upon the Isthmus were never better than now. Yellow fever has been extinct there for three years. The death rate among employees of the Commission and the Railroad during the month of March was at the rate of 8.76 per 1,000 per year, and the men on the whole are a healthy and happy lot. No one thinks any more about his health there than he does at home. The knowledge that certain of the tropical diseases are carried through the medium of mosquitoes, and the careful and successful fight waged by the Department of Sanitation against these pests has made the Isthmus as healthful a place to live as any one would desire. It is not too much to say that the work done by this Department has made the construction of the canal possible, for had the conditions existing on the Isthmus before 1904 continued the force necessary for the engineering work could never have been kept together there.

The Zone has its own police force, operating under the Department of Civil Administration. The cities of Panama and Colon, however, although geographically within the Zone, are nevertheless reserved as Panamanian territory and are policed by the Panamanian force. Conflict of authority is unusual and never has threatened serious complications. Drunkenness is infrequent in the Zone, and crimes of violence extremely rare. This is remarkable when the nature of the population is considered, it being made up with very much more than the ordinary proportion of men in the younger prime of life.

The administration of justice is a part of the Department of Civil Administration, there being three circuit and five district judges. The three circuit judges sitting together constitute a supreme court. Trials by jury prevail only in crimes for which death or life imprisonment may be inflicted.

The recruiting of labor, and the care, repair, and maintenance of quarters, with all matters pertaining thereto, are under charge of the Quartermaster's Department. In general, material purchased by the Purchasing Department in the United States is consigned to the Quartermaster's Department on the Isthmus for delivery through the Depot Quartermaster at Colon.

The Subsistence Department has charge of the procuring and issuing of all subsistence supplies. It maintains sixteen hotels, twenty-four messes for European laborers, and twenty-four kitchens for negro laborers, and in addition operates the Hotel Tivoli at Ancon.

The Subsistence Department is operated through the Panama Railroad, which also maintains a hotel at Colon.

There are separate departments for Disbursements and for the Examination of Accounts, and there is a Purchasing Department organized in the United States, which purchases material upon requisition from the Isthmus. No purchases, however, are made without such requisitions.

There is also a Legal Department concerned with questions arising under the law.

I have endeavored to give you an idea of the exact situation on the Isthmus, and of the plans which are now in process of execution and to show you how thoroughly all of the resident engineering force, and all of its consulting boards, who have visited the work in the last three years, are and have been in sympathy with the project for the lock canal, which the National Congress has adopted, and which has received the sanction of the present National Executive, and of his predecessor.

Further opposition to this plan can have no result except to delay the work. Without such opposition, and with the continued support of the American people, the canal will be finished and in operation in six years from now.

# Concrete Pile Work on the Missouri River

*BY*

Maj. Edward H. Schulz
*Corps of Engineers*

The concrete pile work on the Missouri River opposite St. Joseph, Mo., is the first concrete pile protection work ever used on the Missouri River, and as far as I know, anywhere else.

It has been found that timber pile dikes in the Missouri River decay after seven to ten years in that portion above the water line, and must then be substantially repaired. If a concrete pile dike can be constructed with reasonable economy it will not only be more durable as regards decay, but will not be so readily injured by flood, floating ice or drift.

Proposals were received from various companies, the lowest price being eighty cents per linear foot of pile for supervising the work and furnishing forms and reinforcing material. The United States furnished all other materials, made the piles and drove them. The piles proposed by the different bidders were all to be cast on the ground and were to be driven by jet and hammer combined. The shapes were either to be rectangular or octagonal, with banded steel rods for reinforcement.

In addition to the above, other methods considered were as follows:

*a*. Sinking a core with shell, withdrawing core and filling shell in place.

*b*. Casting the pile in place, the form being gradually removed as the filling proceeds.

*c*. Rolling and making the pile on the ground. The machine alone for this plan made the work too expensive for the small amount to be done.

The details of the piles as driven are as follows:

Total length of dike 150 feet, of which 40 feet was timber nearest the shore, and 110 feet of concrete piles.

Total piles driven 36, total linear feet, 1,457.

Length of piles, 32 to 50 feet.

Penetration average, 21 feet.

Elevation of top of piles, 10 feet above standard low water.

Cross section of piles 14 inches square on top, 8 inches square at base.

Reinforcement: 4 bars of 1 inch square steel, 1¼ inches round tie steel, 18-inch centers.

Forms, 2-inch yellow pine.

Mixture: 1 part cement, 2 parts Missouri River sand, 4 parts crushed rock, largest size 1 inch.

Cement used was Ash Grove Portland.

Age, set 10 days before driving.

The piles were cast on a foreshore at an elevation of about 6 feet above the deck of a barge in the river. Skids were placed from the foreshore to the barge, and as the forms were removed the piles were slid on board, somewhat similar to the handling of wooden timbers of like size.

The approximate weight of a 50-foot pile is 8,700 pounds.

On account of the excessive weight of these piles over wooden piles of the same length, wire cable was used, using a single and double block for increasing the purchase. The hitch for raising the head of the pile was placed about 8 feet from head. The ordinary pile line was used to raise the point of pile, the sling being placed about 15 feet from the small end of pile. This arrangement takes the spring out of the pile. The catenary of a 50-foot pile is about 5 inches without injury to pile.

A device, known as a guide, was placed around the pile near the head in such manner as to hold the pile squarely in the leads. (See Fig. 1.)

The pump used was a single cylinder, double action, 6-inch suction, 3-inch discharge, 1¼-inch nozzle, 60 strokes per minute, and 80 pounds steam pressure.

Method of placing jet pipe: A piece of 1¼-inch pipe was placed in the end of the pile, to which the jet was attached. Other than this the method of sinking was the same as for wooden piles of like size.

The original intention was to experiment with concrete piles only, but as the work progressed it was decided to substitute concrete braces in two of the panels instead of wood. This is shown in Fig. 2.

*Cost of piling.*

| | |
|---|---|
| Invoice for supervising, forms and steel rods | $1,200.00 |
| Portland cement, 86¾ barrels at $1.25 per barrel | 108.44 |
| Crushed rock, 111,800 pounds at $1.30 ton | 72.67 |
| Sand, 32 cubic yards at 20 cents per cubic yard | 6.40 |
| Labor, making forms | 117.00 |
| Labor, making piles | 257.70 |
| Labor, driving piles | 215.00 |
| Total | $1,977.21 |

Actual cost to United States per linear foot, $1.36.

Fig. 1. Driving a concrete pile.

Fig. 2. Completed dike, showing concrete braces.

The actual cost, deducting profit of contractor and cost of special supervision, would be $1.00 per foot.

On extensive work this could probably be reduced to 40 cents per linear foot of pile, as compared to 20 cents for long-leaf yellow pine.

The piles were driven near shore where unusual difficulties existed, due to parts of old dike and rock buried in river bed. Under normal conditions, where only sand is encountered, the pile was jetted in three to five minutes; no hammer was used, but occasionally the pile itself was lifted and dropped to hasten the work. It is believed a judicious use of jet and hammer will be found advisable for future work.

This dike was recently examined after going through an ice and flood season and was found to have stood very satisfactorily. Not a pile or concrete brace was injured, though several wooden braces were broken. Should results continue with similar success, it is probable that concrete dikes will receive serious consideration as a permanent substitute for timber piles on river regulation.

## Prevention of Percolation in Magazines*

The methods heretofore employed to stop percolation are explained in Part I, Annual Reports of the Chief of Engineers for 1900, pages 978, 979, and for 1901, pages 922, 923.

The experiment of using malthoid, cemented to the parapet with pure asphaltum and coal tar pitch, for use in preventing percolation into magazines and other rooms of Battery Wilkeson, as described in report submitted August 17, 1907, was continued during the year. It was found that the malthoid blistered some, but this fault was corrected. The experience of the year has shown that the malthoid as cemented sticks to the concrete parapet effectively, except immediately under and in front of the guns. Its use has continued to be effective in preventing percolation into the rooms of this battery. During June, 1909, the loading platform of emplacement No. 4, Battery Wilkeson, was covered with one-half-ply malthoid, the strips running front and rear, and a second layer of two-ply malthoid laid at right angles. This was cemented with tar and asphaltum and rolled with a heavy roller for three days.

*Abstract of Report of Lieut. Chas. T. Leeds, Corps of Engineers.

# An Early Example of Subaqueous Concrete

[While concrete is by no means a modern invention, it is in recent years that it has come to the front with giant strides. The following report on work done under water seventy years ago is therefore of peculiar interest. Lieutenant W. L. Guthrie, Corps of Engineers, who at present has charge of Oswego Harbor, states that although the concrete was for near forty years exposed to violent storms until protected by the outer breakwater (1871-1881), it is still sound.—Editor.]

Office of Oswego Harbor Improvement,
*Oswego, October 26th, 1839.*

Sir: In accordance with your request, I have the honor to submit a memoir in relation to the use of concrete below water in rebuilding the piers for the protection of Oswego Harbor.

In removing the old wood piers and rebuilding in masonry the present season, it became necessary, in consequence of high water, to commence the masonry 5 feet below the surface.

At the same time it was deemed important, as a measure of precaution against any possible defect in the old pier, which was to form the foundation of the new structure, to cover it with a grillage of strong timber before carrying up the mass of masonry. To insure this grillage being constantly immersed at the lowest stage of the lake required that the demolition should be carried 1 foot lower, or 6 feet below the surface. In order to diminish as much as possible this very tedious and expensive task, it was proposed to dispense with the grillage, and in lieu of it and the masonry below the water line, to overlay the surface of the old pier with a mass of concrete 4½ feet thick. On this substructure rising within 6 inches of the surface of the water, the masonry was to be commenced and carried up 13 feet higher.

It was believed that this stratum of concrete, while it distributed the pressure equally over the whole bearing surface, would afford a foundation sufficiently stable, and far less costly, than one of cut stone masonry. Moreover, from the great rapidity with which it could be placed in position, compared with the tedious process of laying masonry under water, much time would be saved, which in reference to operations on these lakes is most emphatically *money*.

Accordingly, having removed the timber to the required depth, and made the foundation as nearly level as practicable, a curb or sheathing of plank was sunk upon the top course of timbers, and so bolted and seamed as to retain the concrete until it should have time to harden. About 80 feet in length of the pier was thus prepared for the first experiment.

The concrete was composed of broken stone, 2½ inches in diameter, 4 parts; gravel from ⅛-inch to 1 inch in diameter, 1 part; coarse sand not exceeding 1/12-inch in diameter, 3 parts; water lime, 3 parts; water sufficient to temper the mortar.

The mixture when consolidated and well worked together filled 8 measures. It should be observed that the proportion of lime and sand is considerably more than enough to fill the void spaces—an excess deemed necessary on account of the lateness of the season, which required that the proportion of lime should be so chosen as to insure a speedy induration. The mortar, having been first prepared, the broken stone and gravel was spread over it, and the whole thoroughly incorporated by means of the shovel and rammer, and the concrete was then immediately deposited before it had time to set. An iron spoon or shovel, containing 1½ cubic feet, and similar to that used by Captain Bizos of the French Corps of Engineers (a description of which is given by Colonel Totten in his work on mortars and cements), was used in lowering the concrete to its place. This method, although a very good one, is liable to the objection that in sending down such small quantities, much lime is washed out by the agitation of the water and so lost. This difficulty was entirely obviated in the second experiment. An additional 30 feet in length having been prepared as before, two large boxes 4 feet long, 3 feet wide and 1½ feet deep were constructed of thick plank and well banded together—the bottom being divided into two doors opening downwards, which were kept closed when the box was filled by a bolt passing down through the middle, having a catch at the lower and a winch at the upper end, by turning which the contents of the box could be discharged at will. The boxes containing 18 cubic feet were filled and alternately lowered to the bottom by means of a crane scow. The superiority of this process over that of Captain Bizos, or over any other in which the material is sent down in small quantities, is three-fold. The loss of lime by washing is comparatively trifling—the concrete can be well packed in the box by the rammer, and reaches its place in a more compact state. It can be deposited at about two-thirds the expense. I have therefore

given it the preference, and the results of this experiment have been taken as the basis for determining its cost, as given in the estimate for 1840, accompanying my annual report. Having kept a register of the labor and materials applied to filling a known space, I am enabled to speak with entire confidence of the cost of employing it in similar situations.

To prepare and deposit 3,968 cubic feet, the materials being collected within convenient distances of the mortar beds, required:

*Materials.*

| | |
|---|---|
| 310 barrels water lime at $1.27 | $393.70 |
| 1,195 bushels sand at 2 cents | 23.90 |
| 73 cubic yards broken stone at 33 cents | 24.09 |
| 1,000 feet hemlock lumber for sheathing | 6.00 |
| 398 bushels gravel at 1 cent | 3.98 |
| Total | $451.67 |

*Workmanship.*

| | |
|---|---|
| Three masons and overseers, 17¼ days' work at $1.62 per day | $27.94 |
| Common laborers, at 88 cents, 183 days' work | 161.04 |
| Carpenter's work | 2.00 |
| Total | $190.98 |

Cost of 3,968 cubic feet, $642.65, or $4.37 per yard.

It is but fair to bear in mind, when referring to this experiment, in order to determine the cost of using concrete on a large scale, that in two respects the expense is overrated.

In the first place, for reasons stated above, the quantity of lime might be diminished with a corresponding reduction of cost. In the second place, the experiment was confined to a space 30 by 30 feet, which did not allow the tender scow to drop alongside the crane scow, as would be done in ordinary cases, enabling us to dispense with the services of 6 men and 1 overseer. These two reductions will bring the cost within the sum named in the annual estimate or $4.00 per cubic yard. The experience gained in its application would enable me to make still further reductions in the outlay of labor, but even this, it will be observed, is less than the cost of the limestone delivered in its rough state. When to this is added the cost of dressing stone, and the enormous expense of laying masonry in water at that depth, nothing more need be adduced on the score of economy.

A very important consideration is the saving of time. Six work-

ing days sufficed, with the labor of 3 masons and 29 men to deposit 149 cubic yards. With regard to its fitness for the situation to which it is applied, it is required not only that it should sustain the weight of the superincumbent mass, but also that it should be able to resist the shocks, and be proof against the abrasion to which it is exposed.

Time is necessary fully to develop its capabilities, but enough has already elapsed to enable me to speak with much confidence in this regard also.

In the first experiment, the concrete was brought to the required height on the 1st of September; on the 17th, the masonry was commenced and carried up with the usual rapidity. In the second experiment, the stratum of concrete was finished on the 21st, and, fourteen days after, the masonry was laid upon it.

In both instances, the pick and iron-bar were necessary to break down inequalities and level the surface. In doing this, fragments of limestone 3 inches in diameter were frequently broken by the pick rather than quit their hold on the cement in which they were imbedded—a fact which throws some light on its resistance to abrasion.

The masonry of the superstructure is now raised 7½ feet above the concrete. I have minutely examined the joints and applied the level—not the slightest indication of motion or subsidence is perceptible. When it is recollected that time is constantly increasing its power of resistance for years, there can be no longer a doubt of its stability.

If these views be correct, and if my anticipations are realized, we have within our reach a material of construction, which in regard to economy, both of time and money, will be of incalculable importance.

As the results of my own observation and limited experience, these views are submitted with great deference.

By your obedient servant,

JOHN W. JUDSON,
*United States Agent.*

To Gen. T. G. SWIFT,
*Superintendent Lake Oswego.*

# The Relation of Forests to Stream Flow

*BY*

Maj. William W. Harts
*Corps of Engineers*

The claim has been made so often by the advocates of forestry that the deforestation of river drainage basins in recent years is now resulting in higher floods and lower low waters, that it seems worth while to examine some of these rivers to ascertain whether these assertions are founded on truth. Such statements have been widely advertised and so frequently repeated that they have finally come to be popularly accepted. They are reiterated each spring when the usual reports of high floods come in, and the complaints regarding each low water are made use of to confirm them. It may therefore be of some interest to those desiring the facts to know the results of certain recent investigations in this direction, with reference to two of the most important tributaries of the lower Ohio.

A careful study has been made of all the records pertaining to the two principal rivers under my supervision, viz: the Cumberland and the Tennessee. These records refute so positively many of the statements of the advocates of forestry that the connection between deforestation and navigation can scarcely any longer be maintained on these rivers.

These streams are somewhat similar in their upper regions. They take their source in similar country, the southern Appalachian region, and follow the same general direction of flow. Their drainage basins adjoin; that of the Tennessee lying to the south. The tributaries of the Tennessee extend farther eastward and over a much wider range of latitude; the area drained by them being approximately double that of the Cumberland basin. The hydrographic records of these two streams, as far as they have been kept, seem to point out plainly the fallacy of the claim that deforestation is noticeably injuring the navigable capacity of our rivers.

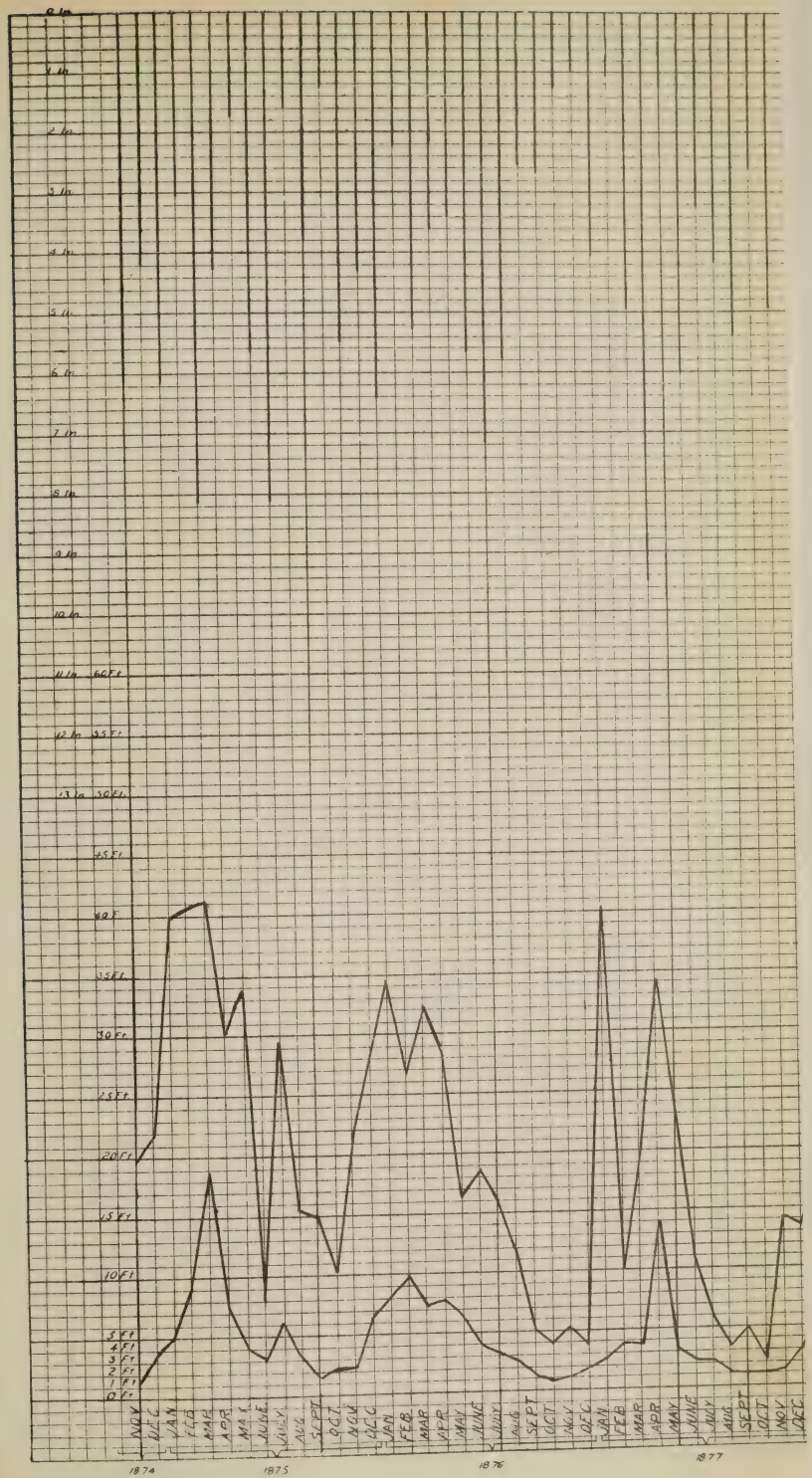
The Cumberland, with its tributaries, has its source in eastern Kentucky and Tennessee at elevations of about 2,000 feet above sea level. The drainage area above Burnside, Ky., is 3,739 square miles.

and above Nashville 11,600 square miles. As is to be expected, the slope of the river and the general grade of the country through which it flows are much steeper in the upper than in the lower portions, the average fall of the river surface from the mouth of Poor Fork to the mouth of Rockcastle River being 3.04 feet per mile; from the mouth of Rockcastle River to Burnside, 2.57 feet; from Burnside to Nashville, .67-foot, and from Nashville to the mouth, .403-foot.

The Tennessee is formed near Knoxville by the confluence of the Holston and French Broad rivers. These tributaries rise in western Virginia and North Carolina at elevations of 2,500 to 3,000 feet above sea level. The drainage area above Knoxville is 10,295 square miles, of which 6,438 square miles belong to the French Broad and 3,857 to the Holston. The drainage area above Chattanooga is 21,418 square miles. The average fall of the Holston from Kingsport to the main river, a distance of 142 miles, is 2.54 feet per mile. The French Broad, from Brevard, N. C., to Leadvale, Tenn., descends at an average rate of 8 feet per mile; while from Leadvale to the mouth its average fall per mile is 2.27 feet. From the confluence of these two rivers to Chattanooga (188 miles), the fall in the Tennessee averages .95-foot per mile.

The country in the vicinity of the upper portions of these river systems is generally wooded, the areas of cleared and cultivated land increasing as we pass down the streams. The river bottoms are often highly cultivated, but the soil of the uplands is generally poor, and owing to the mountainous character of the country surrounding the headwaters these regions are of far less value for agricultural purposes than the valley lands lower down. The areas of cultivated land are increasing, however, and vast areas of timber land have been cut over within the past fifteen years, so that deforestation in these areas is referred to by the Forestry Bureau as already dangerous in extent and as increasing with alarming rapidity. They maintain that it is now affecting adversely the navigable condition of our streams, and that forest preservation is necessary if we expect to protect their navigability from injury.

Exact information as to the areas under forest cover at the present time is very meager, and many efforts to obtain even a close approximation were fruitless; so that the estimates of forested areas given herein are largely based upon conjectures. From the best information available, I should say that the proportion of the drainage basins of these streams under forest cover would now be in the neighbor-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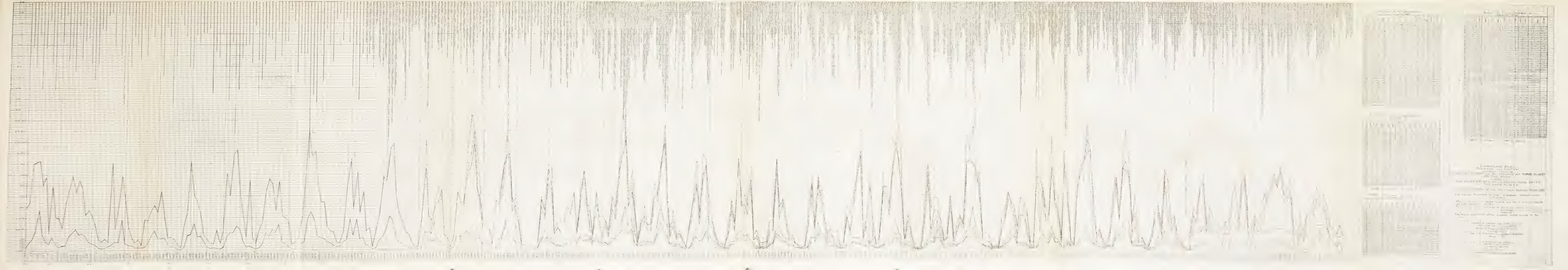


hood of 60 per cent. The increase in cleared areas within the past twenty-five years, including tracts deforested for the sake of lumber, may perhaps amount to as much as 20 per cent. From the census report for 1900 it appears that in Tennessee the increase in the areas of improved farm lands between 1880 and 1900 amounted to 1,749,394 acres; in North Carolina to 1,845,915 acres, and in Virginia to 1,584,692 acres. The changes within twenty years in the lower lands of these States have not been nearly so extensive as in the higher portions, and it may be assumed without much question that the greater part of this increase was at the expense of the forested areas about the headwaters of the streams under examination. The total amount of clearing in the southern Appalachian region is given by the Forestry Bureau as 24 per cent (Report of the Secretary of Agriculture on the "Forests, Rivers, and Mountains of the Southern Appalachian Region," 1902, p. 26); leaving an average of 76 per cent still under forest cover.

The most active lumber operations in the upper drainage basins of these rivers have been carried on within the last twenty years, although lumber began to be cut in large quantities as far back as the early seventies. Lumbermen state that in 1906 far more timber was cut in these drainage areas than in any other year on record. Before the seventies the forested areas in the mountain regions were practically the same as before the advent of the white settlers, deforestation having been slight up to that time; so that a comparison of the river conditions from about 1875 to the present day should show what changes, if any, have resulted from the reported wholesale destruction of our forests. In order to facilitate such comparisons I have had prepared a chart showing the rainfall records and river stages at three places on the Cumberland River, by months, and a similar one for the Tennessee River. The maximum and minimum gage readings at each locality for each month have been plotted and joined by a line, to ascertain whether any noticeable change has taken place in the height or frequency of floods during the period under observation, or whether any marked difference in low waters or their frequency could be detected. Charts have also been prepared showing the rainfall by years as far back as the records are available, to discover if possible whether any change is taking place in the quantity of precipitation, as it has been claimed by some that forests induce rainfall and that deforestation diminishes it.

I have examined these charts with minuteness, but can find no

trace of any effect on the quantities of precipitation or on the fluctuations of stream flow that may be regarded as resulting, beyond question, from cutting off our forests. If any such effect has actually been brought about, it is so slight as to escape careful observation. The indications point in an opposite direction.

Efforts, thus far futile, have been made for years by scientific men to correlate the gage heights of streams with local precipitation records by a mathematical ratio, diagram, or curve, or in some other definite way, so that more or less exact predictions could be made therefrom. This has also been attempted by me from the data prepared for these rivers, but without any results that can be considered valuable. An examination of the tables will show some of the difficulties encountered. The experience of observers in the Weather Bureau also indicates that any such definite correlation would in all probability be unreliable and misleading. So many conditions enter into such a relationship that nothing satisfactory has yet been obtained in this direction.

It has been advanced, however, that some of our streams have deteriorated in navigable capacity, and that this has been in greater ratio than the diminution of rainfall in recent years; thus indicating, it is said, that forest protection is necessary. The arguments presented, when examined closely, often show evidences of "special pleading" and a neglect of pertinent facts. They are, in other words, too often open to the criticism that they have been brought forward for the purpose of "promoting a cause." The tables and diagrams necessary to support such efforts are usually based on wide general deductions, presumably drawn from the best precipitation records available; which, however, as is well known, are only kept at widely distant points and are frequently not characteristic or even representative. Their accuracy is also often questioned, as a strong wind may interfere with the exactness of the quantities shown by the rainfall gage; and at best they are far from being entirely satisfactory. The conclusions deduced from these scanty records are therefore by no means convincing. Nothing, in fact, can be more illusory than the theories sometimes derived from them, and nothing is more dangerous than to jump to wide generalizations from a few inadequate data. Some meteorologists think that the general variations in precipitation and other weather conditions occur in cycles; but the least period I have seen seriously suggested by them is about thirty-five years. Our records do not go far enough back to prove anything of value in this connection, and all efforts to establish run-

off coefficients, curves or diagrams, and formulas which might indicate the river stages that would result under given conditions of rainfall have thus far been practically useless; the lack of success in this direction arising mainly from our insufficient knowledge of all the conditions affecting the problem. Any positive or definite conclusions based on such uncertain data are necessarily very vulnerable.

It will be seen from the charts that the highest water at Nashville was that of 1882, and that high waters for the past ten years have been noticeably less in height and less in frequency than at the commencement of our records. At Chattanooga the highest water was in 1867. During the past few years, which have been rather "dry" years, the high waters in both the Cumberland and Tennessee have been less in height and duration than usual, which might reasonably be expected owing to the smaller average quantities of precipitation; but it is particularly worthy of note that the low waters were not extreme, but *as a rule were higher than usual,* giving better depths for navigation. Although this may be in the nature of a surprise to some, it is plainly seen on the charts and is well established by reliable records. These facts can certainly be of no use in proving that our floods are higher and our low waters lower than before the forests were attacked. If they prove anything it should be the reverse. It may be stated broadly, and I think with positiveness, that the records of the Cumberland and Tennessee rivers do not indicate that the destruction of forests is having any noticeable effect, deleterious or otherwise, on stream flow or on precipitation.

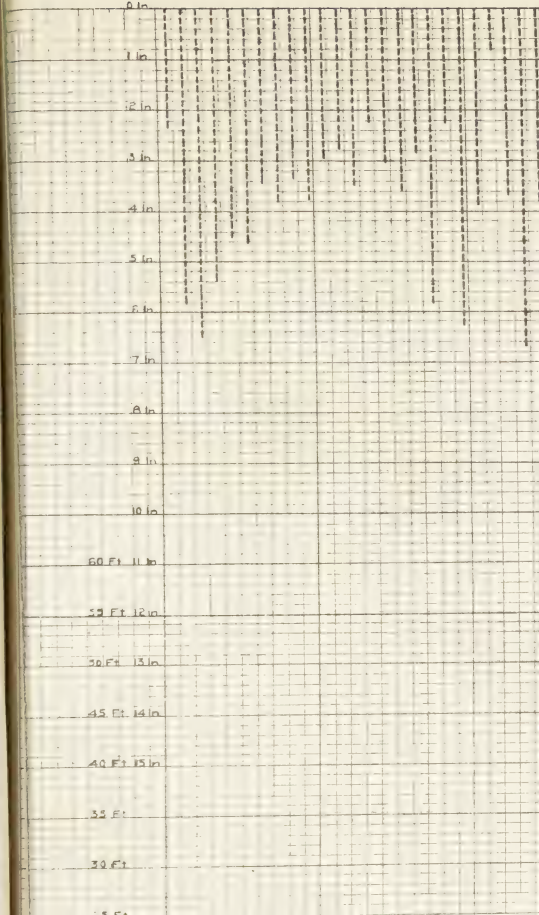
The number of days and the number of times the river at Nashville has been above 35 feet or below 5 feet are shown in the accompanying table. In the last decade, 1899-1908, the stage has exceeded 35 feet but eight times and for 78 days in all; for the previous decade it exceeded this height nine times and for 123 days, and from 1879 to 1888, eleven times and 178 days. This plainly indicates a steady decrease of high-water stages, in both duration and frequency, since 1879. We also find that the river stage was less than 5 feet for 966 days in the years 1899-1904, an average of 161.0 days per year (in 1905-1908 low water was held up by Dam No. 1); in 1889-1898, 1,538 days, an average of 153.8 days per year; in 1879-1888, 1,418 days, an average of 141.8 days per year, and in 1874-1878, 576 days, an average of 115.2 days per year. By examining these averages we see that since 1878 the number of days the river was below 5 feet, or the duration of moderately low

stages, has been increasing; but, on the other hand, in the years 1889-1904 the river reached a stage of less than 1 foot three times and for an average duration of 20.8 days per year; in the preceding decade the river was below 1 foot seven times, with an average of 32.0 days per year; and in 1879-1888, nine times, with an average of 32.5 days per year. It thus appears that extreme low-water stages have not been growing either in duration or frequency during the last thirty years. Any statements that low-water conditions are becoming worse on the Cumberland in more rapid ratio than the decrease in the rate of precipitation are untrue, for they are growing better.

The reason for some of this variation seems clear when we examine the record of rainfall. In the last decade the yearly average was 46.089 inches; in the next preceding, 50.969 inches; in the next, 56.326 inches; while from 1871 to 1878 it was 49.47 inches. This rule of change is thus seen to be substantially the same as for the duration of high-water stages, and may account in part for the low-water variations.

In the case of the Tennessee we find from the gage records that the average number of days the river was above 25 feet was 7.0 from 1899 to 1908; from 1889 to 1898 the yearly average was 9.1; from 1879 to 1888 it was 11.6; and for the four years before 1879 it was 9.3. These averages indicate that for thirty years the *duration* of stages over 25 feet has been steadily declining. Stages of over 35 feet occurred but four times during the ten years from 1899 to 1908, five times in 1889-1898, and six times in 1879-1888. This shows that the *frequency* of high water is also growing less. An inspection of the chart will show that the *heights* are also less of late years, the highest flood having occurred in 1867 and the next highest in 1876. Moreover, we find that from 1899-1908 the river was below 1 foot only twice (1903, 1904), with an average of 10.3 days per year; from 1889-1898 only three times (1894, 1895, 1897), with an average of 7.7 days per year; whereas, in 1879-1888, it was less than 1 foot five times with an average of 20.4 days per year. These records demonstrate that low waters have neither been so frequent nor so low of late years. It is therefore not true that the high waters in the Tennessee River are growing higher and the low waters lower, nor is the frequency or duration of these stages increasing as claimed.

The frequency and height of high waters in both of these rivers, as well as the duration of low waters, follow the rule of precipitation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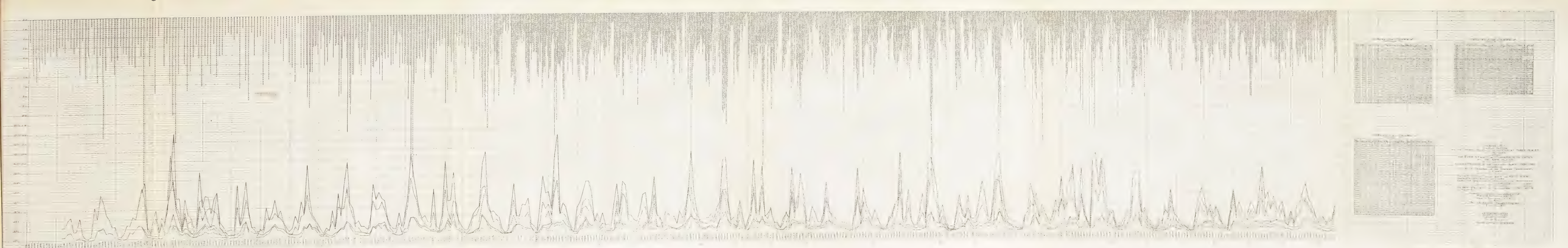

closely enough during the periods under observation to force the conclusion that here is the principal cause of the variations in these streams, and that the introduction of forestry as an important factor in either direction is forced and illogical. Whenever extreme precipitation occurs the river immediately records its effect, and during seasons of light precipitation the corresponding result is to be expected. Temperatures play an important part as affecting evaporation and absorption by the watershed; distribution of rainfall, both in point of time and locality, also affects the river heights; but the extent of this feature is of course not apparent from the data available, owing to the small number of rainfall stations where records have been kept.

It is worthy of note, too, that there has been no falling off in late years in the navigable capacity of the Cumberland River or the Tennessee, due to silting up of channels or any other cause. On the contrary, conditions affecting navigation are distinctly better now than twenty to thirty years ago, even in the portions unregulated. This is largely due, in all probability, to the removal of snags and surface obstructions and the clearing away of overhanging trees. The period of time covered by these observations and the extent of the decrease in forested areas seem ample to show any decided or important change that might be taking place. The records and facts, however, appear to indicate clearly that there is no such intimate or important relation between river stages and forest cover as has been so enthusiastically maintained by the advocates of this theory, nor has the soil wash of the upper regions been raising the beds. No one, I think, desires to detract from the value of forestry as forestry, but it has often been said that the random statements made as to the usefulness of forestry in improving the depth in our navigable streams have unfortunately been much overdrawn, and that the extravagant claims now being urged in this direction have not helped the development of this useful industry. Frequent repetitions may in time create a popular belief in almost anything, but can never alter facts.

The stages which interrupt navigation the most are the extremes of high and low. At either of these, forest cover appears to be of little assistance, or perhaps even a detriment rather than a help. Forest cover of course delays somewhat the run-off of rains, and thus assists materially in promoting absorption by the ground. But these effects are only limited and of small value; the sponge is soon saturated by heavy rains, and floods then occur without hindrance.

In dry weather the forests hold back the small rains, permitting them to evaporate more readily, and thus rob the streams of whatever help they might otherwise have obtained. As pointed out by Colonel Chittenden, it is fortunate that this important industry is not dependent on its relationship to navigable rivers for its usefulness. In their efforts to obtain some constitutional basis for their extensive plans, it is feared that the friends of this valuable department of the Government have imperiled their projects by seeking to furnish reasons for them which are not supported by the facts.

## Notes on Damp-proofing of Magazines*

The cork lining in the magazine of No. 1 emplacement 10-inch battery, Fort St. Philip, which was placed as a test in 1903, had become loosened so badly that it was beyond repair. The lining was cemented directly to the brick walls with which the magazine had been previously lined. Throughout the greater part of the year it was wet and mouldy, and in places had disintegrated. It has been entirely removed and the brick walls scraped and scrubbed to remove all of the cementing material. Thus far, since the removal of the cork lining, there has apparently been less condensation.

The magnesia lumber placed in No. 2 emplacement at the same [illegible] good condition and there is practically no condensation. [illegible] been considerable trouble with percolation in the 8-inch batteries at Fort St. Philip and Fort Jackson. The water apparently came down mostly through the wall adjacent to the hoist wells and followed along the I-beams into the shell rooms and passage ways.

The superior slope of this battery was covered with a thin layer [illegible]t plaster, varying from 2 to 4 inches in thickness. An effort was made to stop the leakage by filling the cracks with "Elaterite," which had proven successful on the platform of the 10-inch battery. But the cracks were too numerous and too small. When the layer of plaster was finally all removed it was found to have but little bond with the concrete beneath, in which slag cement had been used. The concrete was removed to an average depth of 10 inches with a common pick. This space was then filled to the original level with rich concrete put in very wet. Before the concrete had set a wet mixture of the following proportions was put

*Abstract of Report of Lieut. Col. L. H. Beach, Corps of Engineers.

on ¼-inch thick; one sack of cement, three sacks sand, and ten pounds of Wurner's Bitumen Emulsion, thoroughly mixed together. This was allowed to stand twenty-four hours and a second coat of the same proportions and ½-inch thick was applied, which, after being allowed to set, was followed by a third coat. After a few hours the surface was then covered with a 1 to 3 cement mortar, about 1 inch thick, and troweled down very smooth. Since the work was completed there have been unusually heavy and continued rains, but no leaks have developed.

This same material was used in the cable tanks and gave excellent results.

When the cable tanks were first filled and the water had reached a depth of 4 feet, the leakage was equal to the discharge of a small steam pump. During the night the water went down to a depth of 1 foot and remained practically stationary. Upon investigation it was found that the leakage had occurred through a layer of concrete which had been placed in the forms quite dry.

This was removed to a depth of 6 inches and then filled with a rich cement mortar and a small amount of the waterproofing material. Two coats, each ⅝-inch in thickness, thoroughly mixed in the proportions of ten pounds bitumen-emulsion to one sack of cement and three of sand were then applied. The walls of both tanks were covered to a height of 6 feet. The tanks were pumped full on July 13, 1908. During the first twenty-four hours the water surface fell 5/16-inch, and during the first eight days there was a total fall of 13/16-inch. On February 1, 1909, after a period of six and one-half months the water surface had fallen 5¼ inches, which was probably all due to evaporation.

# The Ehrhardt Armored Automobile*

An interesting development of the experiments now being conducted by foreign armies for the attack and defense of air ships is described in the April number of the Kriegstechnische Zeitschrift.

The article describes, under the title "The Ehrhardt Armored Auto-

Fig. 1. Armored car.

mobile for Chasing Balloons," two types of automobiles, carrying special rapid-fire guns, for the pursuit and attack of military balloons.

The cars have chassis of similar type, are both driven by 50 to 60-horsepower benzine motors, and each carries a 5-centimeter rapid-

*Translated from "Kriegstechnische Zeitschrift" by Henry E. Haferkorn, Librarian, Engineer School.

fire field piece. The only difference is in the construction of the upper part of the carriage, one being completely protected, the other being of the open or semi-armored type, as will be seen in the accompanying illustrations. In both cars the armor consists of nickel-steel plate 3 millimeters in thickness. The semi-armored car, while affording less protection for the crew, has the advantages of greater speed and greater stability.

Fig. 2. Semi-armored car.

The armored car weighs 3,200 kilograms, and has a normal speed of 45 kilometers per hour, which can not well be exceeded. It can run over rough roads on grades up to 22 per cent, and is therefore highly mobile. (See Fig. 1.)

The semi-armored car has a normal speed of 50 kilometers per hour, which can be increased to 70 kilometers for emergencies. (See Fig. 2.)

In both cars the seat for the driver is in front, the gun is placed

in the center and the ammunition chest, with seat on its cover, in rear.

Four spuds, operated from inside the car, are let down during firing to secure the vehicle.

The piece is mounted on the side frames of the chassis. It is supported by a pivot at its center of gravity so as to be readily manipulated in the vertical or horizontal direction. An automatic clamp prevents the revolution of the trunnions at recoil. The sliding recoil is controlled by a hydraulic brake and by springs. A

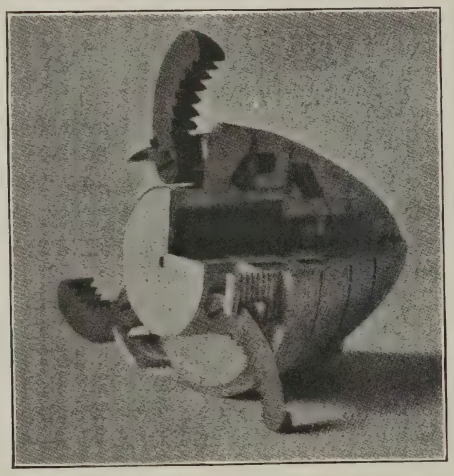

Fig. 3. Shrapnel head.

double trigger arrangement enables the piece to be fired by either of the two gunners. The weight, including carriage, is 400 kilograms. The range of elevation is from — 5 to + 70 degrees.

The ammunition supply consists of one hundred special shrapnel or grenade shells. The shrapnel projectile has an aluminum head which is detached from the body when the burst occurs. This head contains three brass wings which are thrown out by the centrifugal force of the rotation of the head and tear a large hole when it penetrates the gas bag of the balloon. (See Fig. 3.)

While the experiments with the projectiles have not yet reached a final stage, the shrapnel type above described is considered to be superior to the grenade type.

# Lithographic Map Reproduction in the Field

*BY*

Lieut. John A. Holabird
*Corps of Engineers*

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Until the last year our Army, for methods of map reproduction in the field, has been dependent upon blue printing, brown printing, and photography.

None of these methods is entirely satisfactory. The blue and brown printing processes are undoubtedly of great service in making a small number of prints (six or eight) in a short time, but if fifty or sixty prints are desired, even though the fastest paper be used, the method is slow and laborious. Especially is this the case when it is considered that, in all probability, the prints would have to be made at night by artificial light, and a print by acetylene or magnesium ribbon requires six to ten times as long an exposure as by sunlight.

Photography is of special advantage in reducing and enlarging, but the size of print is limited, a dark room is necessary and the apparatus is delicate. Bromide negatives and prints give good results, but require developing and fixing, and then must be dried. The Engineer Field Manual states that fifteen prints an hour may be produced from each negative used in this process.

Although blue-printing and photography both have their advantages and should form part of the reproduction equipment of Engineer troops, yet, for turning out a large number of prints in the shortest time, lithographic methods are undoubtedly the best.

The simple manipulations of lithography will be described in a very general way, to give some idea of the working of this method of printing.

Lithography refers literally to printing from stone, and, as that is still the method most used commercially, it will be briefly considered.

Lithographic limestone very readily absorbs grease. Dilute nitric

acid and gum arabic solution have the effect on the stone of making it resist grease.

On these two principles the process is based.

The stone is ground clean with fine sand and the scratches taken out with a composition "brick" and a polisher; the surface, being now level and free from dirt and grease, is ready for a "transfer."

On a piece of coated paper ("autographic" paper), the design is drawn with a greasy ink. This "transfer" is laid face down on the stone and pulled through the lithograph press, a wooden "scraper" above and a steel roller beneath pressing the stone between them. The paper is then pulled off, leaving the greasy ink on the stone. Now, by washing the stone with a solution of dilute nitric acid and gum (called "etching" the stone), the surface is made to resist further grease, but the greasy lines are unaffected. If, then, the stone is damped, and a roller charged with greasy printing ink is passed over the surface, the greasy lines pick up ink from the roller, but the rest of the stone (having been "etched" and damped) remains clean.

After rolling up, a clean piece of paper is laid on the stone, pulled through the press and a print results. This print is in black lines on a white paper, printed dry, so is ready for use. The impression must be inked up before each print.

A thin sheet of zinc may be substituted for the stone and an autographic transfer made as described for stone. The etching process for a zinc plate is slightly different, but the results are the same.

The autographic transfer has the advantage that the prints obtained are independent of *any kind* of light. The original drawing can be used but once.

There is no doubt that for fieldwork zinc has a decided advantage over stone. A 22 by 28-inch stone weighs about 200 pounds; a plate of the same size weighs about 6 pounds and will, of course, not break as the stone is liable to do. But one or two stones could be carried in the field, necessitating the grinding off of old work to make place for new, while a dozen or more zinc plates could easily be taken, using new plates for new work and preserving the old work for subsequent printing. Old work can be easily taken off of a zinc plate and new work substituted if desired.

Since zinc will be used in fieldwork, it would be well to describe another method of getting the design onto the plate: A method

which depends on light for printing and which comes under the head of photolithography.

The plate is first cleaned with pumice powder, or charcoal, and then sensitized with a solution of ammonium bichromate and albumen. When dry, the plate is exposed to the light in contact with a glass or paper negative; after exposure it is inked up in solid black and placed in clean water. By rubbing lightly with cotton, the ink comes off, except from the lines (where the solution has been made insoluble by the light) and the design is left on the plate; after being etched the plate is ready to print.

The sensitizing solution prints in from two to six minutes in sunlight and in from thirty-five to forty-five minutes by acetylene with one burner to each 50 square inches of map area.

There is a method of printing to zinc directly from a positive; that is, doing away with a negative entirely. This would be of special advantage for fieldwork, for a field sheet inked in could be printed directly to the plate and prints pulled from the plate immediately. By increasing the rapidity of the sensitizing solution so that a print could be made in, say, ten minutes by acetylene, the first print could be pulled from the zinc plate within twenty-five minutes after receiving the inked original.

This method gives, not as one would suppose a print with white lines on a black background, but a print like the original drawing, black lines on a white ground. After printing to the plate, by manipulation the black is changed to white.

Either an autographic transfer or a print to zinc would be used in the field. If the latter process can be worked up (readily possible) so that a print can be made to the plate in ten or fifteen minutes by acetylene it would be much quicker than the autographic transfer, which requires retracing the entire map in autographic ink. A print to zinc gives a much better impression than an autographic transfer.

Although, without doubt, a zinc plate is the best material for field lithography, yet at the present time it has no special advantage over stone, for the reason that there is on the market no hand press for the use of zinc plates alone. The commercial press requires that the plate be laid on a lithograph stone, or, on a raised-steel bed which weighs as much as the stone. The press itself is very cumbersome, one capable of taking a 24 by 36-inch stone weighing over 900 pounds.

What is needed for fieldwork is a light press designed for zinc plates alone. A plate well inked up will give a good print when run

through the rubber rollers of a common clothes-wringer, no bed being required. On this principle, there has been recently submitted a design for a field press which will take a 24 by 36-inch plate and weigh only about 60 pounds.

With such a press, the entire lithograph outfit can be packed in three boxes, the total weight of which will not exceed 400 pounds. This outfit, a hospital tent to work in and a detachment of three lithographers and one draughtsman, could all be transported in a spring wagon, type of the old pattern Signal Corps wagon. Blueprint paper could be carried with this outfit, so that where but few prints are desired this process could be resorted to.

With such an arrangement, the outfit would be compact, easily transported, simple to set up and, being entirely independent, could be assigned to any organization and move anywhere with that organization.

That lithographic work in the field is practicable, even with the commercial press and stone, is shown by the following cases where work was actually done in the field by detachments of Engineer troops who were by no means experienced lithographers.

In August, 1908, a lithographic outfit was taken by Company I, Third Battalion of Engineers, on the march from Fort Leavenworth to Fort Riley.

This outfit consisted of a small hand press (16 by 20 inches) weighing about 200 pounds, a stone (16 by 20 inches) weighing 100 pounds, and a box of materials weighing about 300 pounds.

For each day's march, the reconnaissance squad made a combined road sketch; scale, 3 inches to the mile. This was turned in complete about 4.00 p. m. An autographic transfer was then prepared; scale, 1 inch to the mile, and seventy prints were pulled by 7.30 p. m.

On some days the prints were not completed till after dark, when a kerosene lantern and a small tent to work in rendered the difficulties great.

In August, 1909, a lithograph[illegible]fit was sent to the maneuvers in the vicinity of Boston. The detachment (from the First Battalion of Engineers) had been w[illegible] with lithographic methods for a month only.

The outfit consisted of a pres[illegible]ing about 900 pounds (22 by 28 inches), one double-surfaced [illegible] weighing about 200 pounds, and a box of materials weighing [illegible]nds. Zinc plates were taken but not used, because the men [illegible]ad practically no experience with them.

Although very cumbersome, this was no special disadvantage, as the outfit was assigned to General Wood's headquarters and did not have to be moved.

A hospital tent affording plenty of room and a good acetylene outfit facilitated the work, practically all of which was done at night.

The problem was to print each night fifty-five maps, showing the positions occupied by the Red and Blue armies that day.

In the morning, an autographic transfer (enlargement by pantograph from 1 to 2 inches to the mile) was prepared. The information as to the troop positions, when received, was drawn in and the whole transferred to stone.

At first, two sheets were required, one for each army, necessitating 110 prints in all. The information was received by 6.00 p. m. and the 110 prints made by 9.30 p. m. Later, with both armies on one sheet, water color was put on to distinguish between the two forces. With the information received at 7.00 p. m., 55 prints were made and colored by 9.00 p. m.

Everyone who has seen the work done by these detachments has appreciated the value of lithographic work in the field.

At the present time, men in all three of the Engineer Battalions have had some experience in this process. At Fort Leavenworth, the Third Battalion has worked on lithography for near two years, and is now doing excellent work from zinc plates.

The Second Battalion took an outfit to the Philippines in June, 1909, for use in connection with the map work there.

The First Battalion has had the experience mentioned above at the Boston maneuvers.

The advantage of lithography for map reproduction in the field has for several years been recognized by foreign armies.

In Professional Papers No. 30, Corps of Engineers, the portable outfit of the Royal Engineers is described. This was published eight years ago.

In a book written by a lieutenant-colonel of the German artillery, some fifteen years ago, is a description of a field press for zinc plates alone.

The Russians and the Japanese both used lithographic outfits in the recent war.

At the Boston maneuvers, the Russian, French, and English attachés showed that they were thoroughly acquainted with the process, and spoke of their field outfits.

A field lithographic outfit for our Army is now being considered

and should soon be perfected. One should be assigned to each Battalion of Engineers. While in the garrison there is always plenty of work to be done by a lithographic squad, enough to keep two men as permanent lithographers, these men to act as instructors for assistants to be taken from the four companies. In this way, a lithographic detachment could always be made up with additional men in the companies who could at any time replace casualties in the detachment.

The object of this paper is to point out the fact that at present our map reproduction methods are not as up-to-date as they should be. That by the addition of a portable lithographic outfit a decided improvement would be effected in these methods, and with more experience in the use of such an outfit, engineer troops could, in the field, furnish prints of any character and in any number desired.

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## Map Reproduction*

The topographical department of the Army of the Cumberland consisted of the acting topographical engineers of each brigade, division, and corps staff, and the topographical engineers at department headquarters. The Army was so far from Washington that it had to have a complete map establishment of its own. Accordingly, the office of the chief topographical engineer contained a printing press, two lithographic presses, one photographic establishment, arrangements for map mounting and a full corps of draughtsmen and assistants.

During the first year of the war maps for field use were reproduced by photography, but these maps were objectionable on many accounts. Unless a very fine and expensive lens was used they were inaccurate at the borders, and sections of a large map would not join properly; they faded when exposed to sunlight; copies could not be made at night nor on rainy days, nor could a sufficient number be made even on the best days. For these reasons photography was gradually set aside for lithography; but, as lithographic stones and presses were too heavy for an active campaign, they were left at the depot near the front, and replaced by a facsimile photoprinting device invented by Captain Margedant, chief

*Extract from Report of Gen. W. [illegible] ill on Engineer Service in the Army of the Cumberland.

assistant. This consisted of a light box containing several india-rubber baths, fitting into one another, and the proper supply of chemicals. Printing was done by tracing the required map on thin paper and laying it over a sheet coated with nitrate of silver. The sun's rays passing through the tissue paper blackened the prepared paper, except under the ink lines, thus making a white map on black ground. By this means, copies from the drawing-paper map could be made as often as new information came in, and, occasionally, there would be several editions of a map during the same day. The process, however, was expensive, and did not permit the printing of a large number of copies; therefore these maps were only issued to the chief commanders.

The map of northern Georgia, on which the Atlanta Campaign was based, was made by first enlarging the best printed map attainable to the scale of 1 inch to the mile. This being used as a basis, the details were elaborated by cross-questioning refugees, spies, prisoners, peddlers, and any and all persons familiar with the country in front of us. It was remarkable how vastly our maps were improved by this process. The best illustration of the value of this method is the fact that Snake Creek Gap, through which our whole Army turned the strong positions at Dalton and Buzzard Roost Gap, was not to be found on any printed map that we could get, and the knowledge of the existence of this gap was of immense importance to us. Sergeant Finnegan, of the Fourth Ohio Cavalry, had charge of this branch of the office, and became exceedingly expert in extracting information in this manner.

Two days before the Army started from Chattanooga on the Atlanta Campaign I received notice of the intended march. Up to this moment there was but one copy of the large map of northern Georgia, and this was in the hands of the draughtsman. I kept it back until the last moment, so as to get on it the latest information that Sergeant Finnegan might be able to extract from the motley crew turned over by the provost-marshal general for examination.

The map was immediately cut up into sixteen sections and divided among the draughtsmen, who were ordered to work night and day until all the sections had been traced on thin paper in autographic ink. As soon as four adjacent sections were finished they were transferred to one large stone, and 200 copies were printed. When all the map had thus been lithographed, the map mounters commenced their work. Being independent of sunlight the work was soon done—the map mounting requiring the greatest time; but before

the commanding generals left Chattanooga, each had received a bound copy of the map, and before we struck the enemy, every brigade, division, and corps commander in the three armies had a copy.

The copies for the cavalry were printed directly on muslin, as such maps could be washed clean whenever soiled and could not be injured by hard service. Many officers sent handkerchiefs to the office and had maps printed on them.

Although our map became less and less accurate as we advanced south from Chattanooga, it was still valuable even where its information was defective, because every subordinate commander had the same map as the commanding general, and therefore knew at once from the nature of his orders what he was expected to do. If a road could not be found, still the general direction and the general object of his march could be divined, and the spirit of the general's orders could be faithfully carried out.

I think I am warranted in saying that the army that General Sherman led to Atlanta was the best supplied with maps of any that fought in the Civil War.

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## Formula for Asphalt Pavement*

It may be of interest to mention the present condition of asphalt pavements laid in 1898 on the loading platforms of Batteries Read and Gibson, Fort Du Pont. The pavements are now in good surface and condition and so hard that they show no marks from wheels of shot trucks or other traffic. The pavement in gutters was relaid in 1907, but no repairs have been made to the body of the pavements and platforms. Some irregular cracks have developed in places, but they do not extend through. The top surface is worn so the grit, duck-shot size, shows. It is believed that there is no better pavement for use on loading platforms. The pavement was laid 1 inch thick, in two layers to break joints, and cost, in 1898, $1.53 per square yard, sand being furnished by the United States. The formula for the mixture is as follows:

Fifty per cent Seyssel Asphaltic Mastic; 35 per cent grit, duck-shot size; 10 per cent clean, sharp sand; 5 per cent bitumen.

*Abstract from Report of Maj. H. Deakyne, Corps of Engineers.

# A LETTER AND A CIRCULAR

DEPARTMENT OF WAR,
*September 6, 1841.*

SIR: Information received at this Department from various sources has induced the apprehension that no inconsiderable portion of the funds provided by Congress for purposes connected with the National defence, has been applied to objects or in modes not contemplated by law, such as salaries to unnecessary officers or agents, and excessive expenditures on the quarters and grounds occupied by officers, owing to a scale of size and style of finish not required for the public use or convenience. As it is the imperative duty of the Executive to see that all appropriations be scrupulously applied for the advancement of the beneficial objects for which they were intended; and as it is the design of this Department rigidly to enforce this duty, in order to facilitate the accomplishment of these important objects, you are desired to report, as soon as practicable, upon the following points:

1. Whether the plans of some of the works, as well as those partly constructed as those only projected, may not be advantageously reduced? If any, name them, and the character and amount of reduction.

2. Whether the style of building and the materials used may not to some extent be changed without injury to the efficiency of the work, but with great saving of expense?

3. Whether there is not unnecessary expenditure in building and furnishing officers' quarters, preparing greenhouses, gardens, and other objects designed more for personal gratification than for public use?

Where instances of this kind have occurred, state them, with circumstances and amount.

4. Whether excessive prices have been paid for sites of works? If so, state instances and amounts.

5. Whether excessive prices have not been and now are, paid for materials? If so, state cases, and suggest the proper corrections, and

the best mode of guarding against such abuse in future. Your particular attention is requested to this branch of the inquiry.

6. The number of each grade of Assistants, Agents, Clerks, Superintendents, etc. (excluding only the mechanics and laborers) employed under your orders, or in anywise connected with the public works under your charge, according to the last returns; stating their stations, duties, pay, emoluments, allowances and privileges, with a comparative statement of the compensation obtained for similar services in civil employments contiguous to these works.

Where reductions of numbers or rates of compensation may properly be made, state the circumstances, and where agents or assistants are needed, and the present incumbents are inefficient let them be named.

Reposing great confidence in your zeal and ability, the Department trusts that you will apply yourself particularly to the retrenchment of all unnecessary expenses, and to the enforcement of such wholesome regulations as will secure the strict observance of the public interests committed to your charge.

The large appropriations, recently made by Congress for these objects, renders it still more obligatory upon the Department to search out all sources of useless or extravagant expenditures, and to enforce greater vigilance and more strict economy in the due application of the public money to the important objects for which they have been thus appropriated.

Very respectfully, your obedient servant,

JNO. BELL.

COL. L. G. TOTTEN,
*Chief of Engineers.*

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[CIRCULAR.]

ENGINEER DEPARTMENT,
*Washington, 13th September, 1841.*

SIR: I transmit herewith the copy of a [illegible] received from the Secretary of War, calling for a report, as [illegible]as practicable, upon certain points therein specified, touching u[illegible]sary or extravagant expenditures of funds provided by Co[illegible] for purposes connected with the National defence.

This Department does not doubt that th[illegible]ehension expressed by the Secretary of War although "founde[illegible]nformation received

from various sources," is, as regards the operation in charge of this office, entirely groundless—the apprehension has, however, been raised, and whatever may have been the motives or sources from which it springs, it has become necessary both to the professional honor and reputation of the Corps of Engineers and to the successful prosecution of the great cause of National defence, that it be removed.

The trust especially committed to the Corps of Engineers is one of the greatest, both as to cost and consequences, connected with the military service; and the reliance on professional capacity, judgment, prudence and honor, which, in a peculiar manner, it implies on the part of the Government, must not be impaired. The officers therefore are called on to present such explanation on the several points indicated in the Secretary's letter as shall be entirely complete—leaving no matter that might seem to be included untouched or unexplained; doing all carefully, with precision, and in the spirit of frankness.

On the first point, it is probable few of the officers will have any observations to make.

On the second, they will particularly describe the principal materials used, the mode of preparation in reference both to the quality and appearance of the work, and the mode of construction; and in order to the better understanding thereof, they will compare as to difference in cost and effect, the work as executed with a supposed use of cheaper materials and workmanship.

On the third point, the officers will describe accurately and clearly anything that has been done with a view to the personal accommodation of those connected with the works—particulars will be gone into on all the matters included under this head. If a single expense (ever so small) of this nature has been incurred, the exact circumstances, the time, and the amount will be fully set forth.

If any information can be communicated on the fourth point, it will be stated.

The fifth point will be fully elucidated; and in doing it much required under the second may need to be repeated.

The sixth point is also to be attended to in every particular, and in both branches.

However satisfactorily this whole matter may be cleared up to the Government—and that the explanation will in all things redound to the honor of the Corps the Chief Engineer does not permit himself to doubt—the imputation conveys a lesson. I should rather say

*repeats* a lesson which should be ever before us; namely, that industry, the application of all one's faculties, a single eye to the public good, the most untiring zeal, afford no security against calumny and misrepresentation, or the bitings of petty jealousies. As to ourselves, we might treat these things with the contempt they merit, but unhappily they, however, unjustly affect the public interest through us—they poison the public mind, and destroy its confidence and the confidence of the Government in one of its greatest military concerns. It is necessary, therefore, that there should be a circumspection attending all the measures of our officers that will anticipate and prevent all misunderstanding and misrepresentation; and in this view it was that the new regulations of the Department were drawn up—they do not, probably, guard every point, but as it is believed that an undeviating adherence to them will do much to prevent any future imputation of this sort, it is my duty to call particular attention to them.

Very respectfully, your obedient servant,

GEO. L. WALKER,
*Lieutenant and Assistant Chief Engineer.*

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## Ventilation of Engine Room*

A General Electric 25 K.W. gasoline-actuated generating set was installed in a former storage battery room in Batteries Rodney and Clermont Best, the entrance to which is through a 5-foot passage 52 feet long, the room being therefore practically without ventilation. The location of the water-cooling fan was therefore important to secure a proper circulation of air in the engine room to keep the cooling water at the proper temperature and to drive out gas which escapes, more or less, from the engine into the room. After experimenting by placing the cooling fan at different places, the arrangement shown in Fig. 1 was found to give perfect ventilation and was adopted. The exhaust from the engine is discharged through a 6-inch pipe extending from the ceiling of the room to the top of the earthwork, formerly used for ventilation with the storage battery. The discharge from the cooling fan, about 10,000 cubic feet of air per minute, is through a duct 17 inches high by 5 feet wide, constructed in the top of the entrance passage, a hinged door at the outlet which can be set at the proper angle to direct the current of hot air upward so it will not mix with the cool air entering below. The engine is being operated daily, except Saturday and Sunday, and the temperature of the concrete walls of rooms is such that there is no condensation at any time. The temperature of the engine room varies, of course, with the temperature of the outside air. Observations during hot days show a temperature of not more than 10 degrees above that of the outside air.

*From Report of Maj. H. Deakyne, Corps of Engineers.

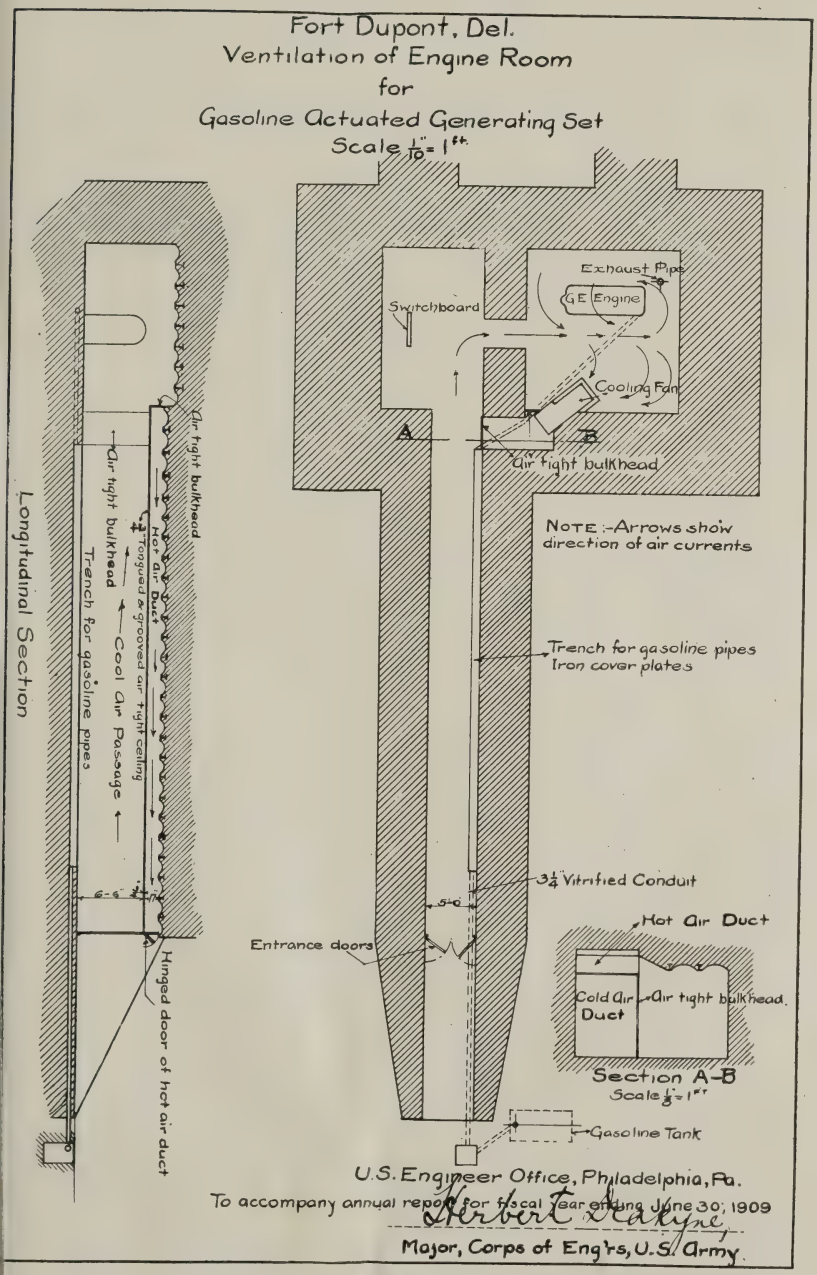

Fort Dupont, Del.
Ventilation of Engine Room
for
Gasoline Actuated Generating Set
Scale 1/10" = 1 ft.
Longitudinal Section
Air tight bulkhead
Air tight bulkhead
Hot Air Duct
Tongued & grooved air tight ceiling
Cool Air Passage
Trench for gasoline pipes
6-6
Hinged door of hot air duct
Exhaust Pipe
G E Engine
Switchboard
Cooling Fan
A
B
Air tight bulkhead
NOTE :-Arrows show direction of air currents
Trench for gasoline pipes
Iron cover plates
3¼ Vitrified Conduit
5-0
Entrance doors
Hot Air Duct
Cold Air Duct
Air tight bulkhead
Section A-B
Scale 1/8" = 1 ft
Gasoline Tank
U.S. Engineer Office, Philadelphia, Pa.
To accompany annual report for fiscal year ending June 30, 1909
Herbert Maltyne,
Major, Corps of Engrs, U.S. Army.

Fig. 1.

# WATER POWER ON THE OHIO RIVER*

PART I.

*The possibility of using the water power at the movable dams on the Ohio River for the purpose of operating the power plants for improving the lock and dam.*

As power is needed for various operations when the water power would not be available, it does not seem that this water power can wholly supplant the present power arrangements at the various locks. For instance, it is necessary that the lock gates be kept open when the dam is down, and at least one of the gates must be moved before the dam is raised and water power is available. The opposite of this occurs when the dam is lowered and one of the gates must be moved after the dam is down. To provide for these movements of the gates, for the operation of the lock and dam during breakdowns in the water-power plant, for the operation of the machine shop when the dam is down, etc., it is necessary to either store power or to install an auxiliary power plant.

Storing compressed air is not practicable, and since compressed air seems the most feasible and has been adopted for operating the locks and dams, the storing of any power to be later converted into compressed air would entail an expense for additional machinery probably greater than the cost of an auxiliary power plant of steam, gas, or electric motors. Therefore the Board will consider the installation of a water-power plant to develop sufficient power for the entire operation of the lock and dam, to be used whenever possible and continuing the use of one-half of the present power-plant design as an auxiliary plant.

The head of water available at each lock is the lift of the lock less the loss in head and tail races for the turbines. The lift of the locks will be assumed at 6 feet, which is about the minimum lift of Locks Nos. 8 to 26, inclusive, as proposed by the Board of Engineers for the Ohio River in their report dated December 15, 1906.

Where a lock has a theoretical lift of 12 feet, this difference in ele-

*Report of a Board convened by Capt. [illegible] Altstaett [illegible]s of Engineers, consisting of Mr. Frank D. Holbrook, Assis[illegible]gineer, [illegible] B. Duis, Assistant Engineer, and Mr. William N. Dambach, Junior Engineer.

vations of the pools will occur at approximately low water only; at higher stages, when the dam is up, the difference in pool levels will be less, possibly as small as 5 feet at times. A head of water of 5 feet is about the least that can be feasibly utilized for power purposes, therefore but a very small loss of water-head can be allowed in head and tail races. To meet this condition the canals or conduits leading to and from the turbine must either be very short, or, if long, of large sectional area to admit of a small velocity for the water current.

The required power for operating the locks and dams has been determined in the machinery designs to be 100 horsepower. Allowing 10 per cent additional for speed regulation, 80 per cent for efficiency of the turbines, and an effective water-head of 5 feet, the water required per second to develop the power will be $\frac{550\ (100 + 10)}{62.5 \times 5 \times .80}$, or, approximately, 250 cubic feet. Placing the turbines at the lock, except in the river wall, makes necessary very long head and tail races, extending from the upper pool above upper gate, around both gate recesses; and into lower pool below lower gate. The head and tail races together would be about 1,000 feet long, and for a capacity of 250 cubic feet of water per second with a maximum allowable loss of head, say 6 inches, the conduit for the races would be 9 feet in diameter if circular in section. The expense of constructing such a conduit and the necessary wheel pits would be great, and the loss in water-head of not less than 6 inches a serious detriment to this scheme when the available head is already so low. It is not considered necessary to go into further consideration of this plan, for a location giving more efficient head for power and decidedly more economical in cost of construction, is available in the river wall of the lock. The Board considers this the most feasible location for a water-power plant of the size necessary for operating the lock and dam and in accordance with this view, submits a general plan for such a plant.

Figure 1 shows this plan. The river wall at the end of the navigable pass is widened to 20 feet, which gives space for installing the turbines and for a conduit for discharging the tail water into the lower pool. The full height of the water in the upper pool can practically be maintained over the turbines and a not very appreciable loss of head will be caused by the short tail race. The turbines can be directly connected to the air compressor by means of bevel gears and shaft. For protection during floods, etc., the compressor

can be of a type having all its working parts in a water-tight encasement. The air compressor will discharge into a pipe leading to the air storage tanks in the power house.

In estimating the cost of such a power plant, allowances must be made for the need of only one-half of the present proposed power plant; also, the cost of the power house can be reduced by decreasing the sizes of the engine and boiler rooms. Based on these considerations, the net increase in first cost of the power plant is derived as follows, the different items in the estimate having been figured in as much detail as the general design admits:

| | | |
|---|---|---|
| Widening and raising river wall of lock, including foundation, for length necessary to contain the plant | $6,000.00 | |
| Steel screens at head of intake culverts | 200.00 | |
| Head gates in intake culverts, with operating machinery | 600.00 | |
| Steel grillage in turbine and air compressor floors | 1,200.00 | |
| Two 50-inch turbines with governor | 2,000.00 | |
| Air compressor, capacity 500 cubic feet free air per minute, 100 pounds pressure, with harnessing gear to turbines | 2,500.00 | |
| Pipe from air compressor to air storage tanks in power house, with valves and connections | 1,000.00 | |
| Total | | $13,500.00 |
| *Possible reduction in cost of the present standard power house and machinery:* | | |
| One gas engine, 100 horsepower | $4,000.00 | |
| One air compressor, same capacity as one named above | 2,000.00 | |
| Decreased cost of power house, due to less space needed for engine and boiler rooms, approximately | 5,000.00 | |
| Total | | $11,000.00 |
| Net increase in cost for installing water-power plant | | $2,500.00 |

The depreciation and maintenance cost of the present standard power plant and the one here considered will probably be about the same; also, the cost of superintendence and labor for operation. There remains, then, to be considered the difference in cost of operation, on account of fuel, for the gas or steam plants.

The power required for one lockage has been assumed in present adopted power plants to be 100 horsepower for twenty minutes, or 33⅓ horsepower-hours. With natural gas for fuel, the average consumption of gas in a well-designed gas engine is about 12 cubic feet per horsepower-hour. Taking the present price of natural gas

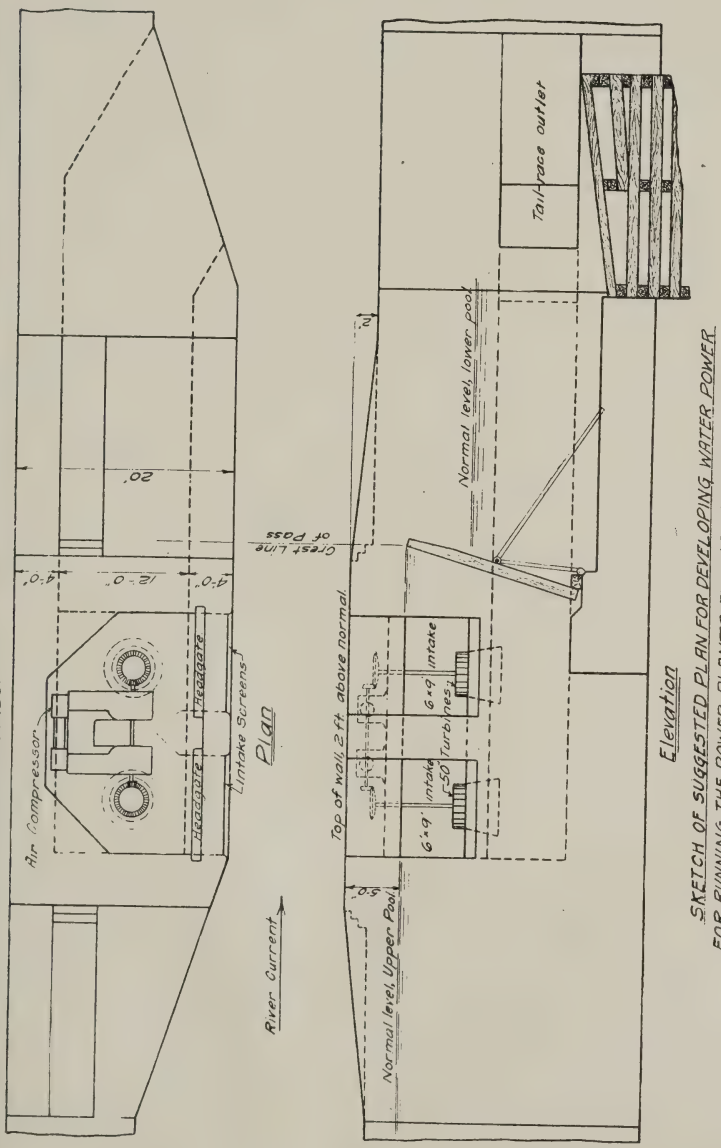



FIG 1 4

SKETCH OF SUGGESTED PLAN FOR DEVELOPING WATER POWER FOR RUNNING THE POWER PLANTS AT THE MOVABLE DAMS ON THE OHIO RIVER
Scale 1 inch = 1 foot

for a basis, which is about twenty cents per 1,000 cubic feet, the cost for fuel in a gas engine for one lockage is eight cents. Fuel for power will also be used for other purposes, such as operating the bear-trap weirs, and, on account of losses of power due to leakage in air pipes, receivers, etc. To provide for this 25 per cent, in addition to the above cost of fuel for operating the locks, will be allowed, making the total estimated cost for fuel ten cents per lockage.

Producer gas from anthracite or bituminous coal is a cheaper fuel than natural gas, but the additional expense for installing a producer-gas plant is more than the extra expense necessary for constructing the water-power plant, therefore a producer-gas plant is obviously not as economical for power as the water-power plant, since the use of the latter makes necessary but a small expense for fuel for the auxiliary plant. Power from steam is not only more expensive for fuel than from natural gas, but the cost of installation of the plant is greater, so it also need not be considered. It then remains only to complete the comparison for economy in construction and operation of the present adopted power plant of gas engines using natural gas for fuel, with the suggested water power and auxiliary natural-gas power plant. The former is estimated to be $2,500 cheaper in first cost, but the latter, having a small expense for fuel, is less expensive for operation. Assuming 2½ per cent annual interest on the $2,500, which is the excess in the estimated cost of the latter plant over the former, and which interest will amount to $62.50 per annum, and ten cents as the cost for fuel for each lockage as before shown, it will require 625 lockages per annum for the water-power plant to save enough in fuel to pay for its greater first cost.

The Davis Island Dam was up for an average of one hundred and fifty-two days per year for twenty years. On that basis 625 lockages per year would be only 4 per day during the probable time a lock is in operation, and it is to be expected that this number of lockages will be greatly exceeded when the whole system of locks and dams on the Ohio River is in operation. The Board appreciates, however, that the above figures show that even a small error in the above-estimated difference in first cost of the [illegible] plants might produce a result that would not allow quite the sa[illegible]nclusions given above, but it is thought that any such error wou[illegible] rather in the direction more favorable to the water-power plant [illegible]ust also be taken into consideration that the assumed cost [illegible]ural gas is based on

present prices, and it is entirely probable that in the future prices will be higher and even possible that the supply will fail entirely. It is also probable that the locations of some of the locks and dams will be so far removed from a source of supply that natural gas will not be available for power purposes.

In proposing the above scheme of water-power development for operating the dams, the question might arise as to the amount of water available for this purpose during periods of extreme low water.

The discharge of the upper Ohio River during the extremely low stage of 1908 was approximately 1,100 cubic feet per second, determined from measurements made at Dams Nos. 6 and 8; and at this stage it was found to be possible to maintain the levels of the pools in the Ohio River in the Pittsburg district and make such lockages as required. While unusual means were employed to accomplish this, even then considerable water was lost in leakage through the dam.

There is no appreciable increase in the amount of the low water discharge until the Muskingum and Little Kanawha rivers are reached, but below these two streams to the mouth of the Great Kanawha River the discharge is approximately 1,400 cubic feet per second.

The water necessary to produce the power for operating a lock has been previously shown to be 250 cubic feet per second with a 5-foot head. During extreme low stages of the river the head at a dam will be practically equal to the maximum lift for which it was built, and which lift has been previously assumed to be a minimum of 6 feet. Therefore, when the discharge of the river is at a minimum the water head will be at a maximum, and the water required for power purposes at such times would not be 250 cubic feet per second as previously determined, but only about 200 cubic feet per second for the 6-foot lift. At only a few of the locks in the district in question will the lift at extreme low water be as small as 6 feet. At some it will be as great as 10 feet. Therefore the average amount of water required for power purposes will be that corresponding to about a 7.5-foot lift, or, about 160 cubic feet per second. Taking the most unfavorable case, which is a lock with the minimum lift and above the mouth of the Muskingum River, the proportion of the water required for power to the total water discharged by the river would not be as 200 to 1,100, for the power plant would be in operation only during such times as lockages were being made. For ex-

ample, if twenty lockages per day were being made and each lockage required the operation of the water-power plant for twenty minutes, it would be operated but 28 per cent of the total time and the water required for power would be an average of 56 cubic feet per second, or about 5 per cent of the total discharge of the river. In this case if the low-water discharge of the river, economically conserved, is only slightly more than sufficient to provide for navigation, the small amount of water used in the development of power would not lower the pools sufficiently to interfere with navigation, nor so much but that they would again attain their normal levels in the periods between the intermittent operation of the locks. Below the mouth of the Muskingum and at a lock of any greater lift, the percentage of the total discharge used by the water power would be less; in fact, the increase in the low-water discharge is sufficient to operate the power plant.

Even though the assumed number of lockages be doubled, viz: forty per day, the possibility of a scarcity of water for power purposes is of small consequence as a factor against the feasibility of operating the locks and movable dams by water power; for the low discharge of the river, as here assumed, is of infrequent occurrence and usually of short duration, and if at such times no water could be diverted to power uses, the auxiliary power plant would be available for such an emergency.

Based on what has been herein set forth the Board expresses the following conclusions:

Where natural gas can be used for power at a price not greatly exceeding that assumed in this report, there would be at the present state of navigation on the river no material difference in the total cost of operating the locks and movable dams on the Ohio River if water power were used when available instead of power from gas engines.

Where natural gas for power exceeds very much in cost that mentioned above, or where it is not available at all and power from steam or producer gas must be used, the use of water power would be economical.

When the traffic on the Ohio River has been so developed that the locks will be operated more often than assumed in this report, the use of water power will be economical at all the dams.

From the favorable showing brought out for the use of water power under certain conditions, it is deemed advisable by the Board that the scheme of water-power development in connection with

auxiliary power from other sources as proposed should be considered in more detail than is possible within the scope of this report, so that its practical value may be more closely determined.

PART II.

*The development and utilization of water power for industrial and commercial purposes on the Ohio River between the Pennsylvania State Line and Dam No. 26.*

In the investigation of the development and utilization of water power for industrial and commercial purposes in connection with the movable dams on the Ohio River, the problems for consideration naturally present themselves and will be taken up in the following order:

*A.* Average amount of time during the year the dams will be up and power may be obtained.

*B.* The available head at the dams and the amount of water that can be diverted for power purposes.

*C.* The location and kind of plant for developing and distributing the power.

*D.* The cost of the power so developed and its value in competition with power obtained from other sources.

*A.* The first of these problems to be considered will undoubtedly have the greatest bearing on the conclusions in this report and at the same time it presents the most difficulty in its solution, for it applies to the river after the movable dams are constructed and in operation, while the data at hand for the part of the river in question are for an open river only. It is therefore necessary to establish the relation of the operation of the movable dams, if they had been in operation, with respect to the stages of the river in its open or natural condition as shown by the hydrographic records. For this purpose a study of the conditions under which the completed dams in the Pittsburg district have been operated has been made, especially at Dam No. 6, where gage readings are available for the open river below at times of raising or lowering the dam.

As the result of this study of conditions, the following assumptions have been made for the purpose of estimating from gage records the periods when the movable dams, if in operation, would have been up; that the season during which it is practicable to operate the dams extends only from April 1 to the end of the year, for during the period from January 1 to April 1 the river is generally at

too high a stage, or, if low, too much congested with ice to permit the operation of the dam; that the approximate maximum stage at which the dam can be raised is that corresponding to a stage of 7 feet above low water in open river; that the dam must be lowered at a stage corresponding to about 9 feet above low water in open river; and that above the mouth of the Great Kanawha River, during stages less than 1 foot above low water in open river, the discharge is so small that little or no water is available for water power.

On this basis Table I has been prepared, showing the number of days per year for different stages of the river during several years in the past when power would have been available. This table also shows the probable number of interruptions that would have occurred to the water power, if developed, due to the lowering of the dam on account of freshets and to the periods when the discharge is so small that no water is available for water power. It was found that in the Pittsburg district it took an average of about 5.7 hours to raise the movable dams and about 2.3 hours to lower the same, and usually the pools filled in a few hours; these data were also taken into consideration in preparing the table.

The results shown in Table I are summarized in Table II, except that in computing these final averages the results for below the mouth of the Great Kanawha River shown in Table I were not included for the following reasons: The low-water discharge of the Ohio River at the Pennsylvania State line is about 1,100 cubic feet per second. This is derived from the measured low-water discharges near Dams Nos. 6 and 8, hereafter shown in Table IV, and between which points no tributaries having an appreciable flow at low water times enter the river. From the Pennsylvania State line to the mouth of the Great Kanawha River the only tributaries that will be considered as appreciably augmenting the low-water discharge of the Ohio River are the Muskingum and the Little Kanawha rivers. The Board has not been able to find any data giving the low-water discharge of the Muskingum River, but from descriptions of the river in various reports concerning its improvement for navigation, it is inferred that it is very small. This may be verified indirectly by means of discharge measurements made in 1892 at Davis Island Dam and below the mouth of the M[illegible]gum River, shown in Annual Report for 1893 of the Chief [illegible]gineers, United States Army, page 2459. These discharges, [illegible]ed at a stage of about 1 foot above low water and apparently [illegible], a stationary period of the river, show an increase of only abo[illegible] cubic feet for both the

Beaver and Muskingum rivers. It therefore seems safe to assume that the low-water discharge of the Muskingum River does not exceed 300 cubic feet per second.

A low-water discharge of 13 cubic feet per second has been determined for the Little Kanawha River as shown in the Annual Report for 1875 of the Chief of Engineers, United States Army, page 746. From the foregoing data it would seem that the low-water discharge of the Ohio River above the mouth of the Great Kanawha is approximately 1,400 cubic feet per second. In the Annual Report for 1876 of the Chief of Engineers, United States Army, page 749, the low-water discharge of the Great Kanawha River is given as 1,100 cubic feet per second. Therefore, the flow of the Ohio River at low water is increased about 80 per cent by the Great Kanawha, and for stages up to a few feet higher it is probably in about the same proportion. This is too great a change in the flow of the river to permit combining the data above with those below for a general study of water-power development. Therefore, it was not deemed advisable to take into consideration the data of the river below the Great Kanawha in making up the final results in Table II, but, if desired, the final conclusions reached in this report for above the mouth of the Great Kanawha can be applied to locations below by considering the difference in the discharge of the river for same stages above low water.

For a general comparison and checking of the results in Table II, the maneuvers of the Davis Island Dam are given in Table III. A comparison of Tables II and III will show that in the former the averages of the amount of time the dams would have been up are generally somewhat greater than the same shown in the latter and which actually occurred. This difference is probably explained by the fact that on account of some of the weir area not having been used in the maneuvers, the Davis Island Dam is raised and lowered at lower stages of the river than assumed for compiling Table I.

Table II shows the probable average number of days during the years considered that the dams would have been up for each of the several stages of the river when water would be available for power. Assuming the same conditions for the future, then for one hundred and sixty-one days of the nine months per year considered, a stage of not less than 1 foot may be expected, and for one hundred and thirty-nine days of that time a stage of at least 2 feet should occur. Similar deductions may be made for the rest of the time when the dams would be up. After deducting the amount of water lost in

leakage through the dam and that used in lockages, a stage of 1 foot does not give a very large surplus of water for power, while a stage of 2 feet or over will give a surplus that makes the development of water power more practicable and this stage will exist for an average of only twenty-two days less per year than the stage of 1 foot or more. For the higher stages it seems evident that the increase in available water for power is more than offset by the decrease in time that it is available, since the total time for obtaining any power is already small for economical development.

The Board therefore concludes that the purpose of this report is best fulfilled by continuing the investigation on the basis of the power that can be developed at a stage of the river of 2 feet or more, and that it will be available for one hundred and thirty-nine days per year.

For twenty-two days more per year somewhat less power may be obtained, perhaps an average of half as much. Also, as shown in Table II the one hundred and thirty-nine days of power per year will not be continuous but will be interrupted on an average of three and one-half times and these periods of interruption will vary from a few days to several weeks on account of high water, and may last for several months due to an extremely dry season and continued low water.

*B.* In considering the second question, the lift of the locks upon which the head of water at the dams depends is taken to be 6 feet, which is about the minimum adopted by the Board of Engineers for the Ohio River, in their report dated December 15, 1906, for that part of the river now under consideration. The head of the water at the dams, however, will be appreciably less than the lifts for which the locks are designed except during approximately low-water periods. Including additional losses of head in forebay, tail races, etc., it is thought that there will be an effective head for power of at least 5 feet during nearly all of the time when the dams will be up.

The water that can be diverted to power uses at a 2-foot stage is the discharge of the river less the leakage through the dam and the water used for lockages. In Table IV are shown all the discharge measurements, made of the Ohio River from Dam. No. 6 to Dam No. 26, that could be obtained. Those at Dam No. 6 were at or near low water only, while at Wheeling none are for a stage less than 3.45 feet above low water. For obtaining the discharge for a 2-foot stage above the mouth of the Great Kanawha River, then, only those measurements made near Dams [illegible] and 18 are of value.

Those near Dam No. 8 are of a value and sufficient in number and range to accurately determine the discharge curve from low water to about 7.5 feet above. The measurements near Dam No. 18 seem to be of good value, but are deficient in number for definitely determining the discharge curve within the range covered by the measurements. The discharge curves for the two points are shown at end of Table IV, and by means of these curves the discharges of the river during a 2-foot stage at Dams Nos. 8 and 18 are 5,000 and 6,000 cubic feet per second, respectively. For the purpose of this investigation, the average discharge of the Ohio River at a 2-foot stage and between the Pennsylvania State line and the mouth of the Great Kanawha River will be taken as the means of those at Dams Nos. 8 and 18, which is then 5,500 cubic feet per second.

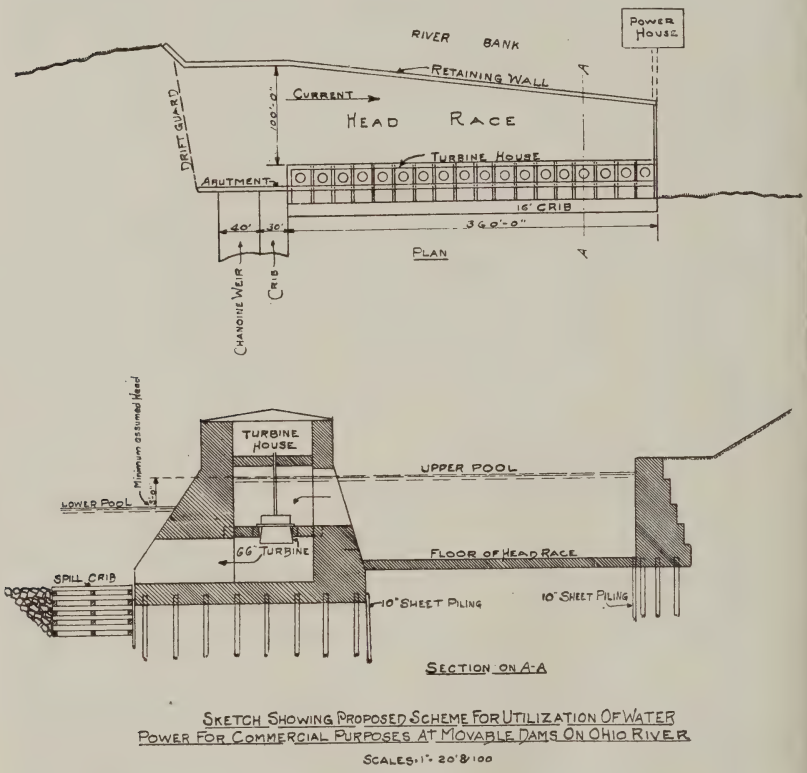
The amount of water lost in leakage through the dams can be approximated only. During the very dry season of 1908, when the discharge, as before mentioned, was about 1,100 cubic feet per second, it was found possible in the Pittsburg district to hold the pools of those dams now in operation at their normal level, but at this time there were relatively few lockages made. Therefore, it is assumed that the same flow will be sufficient to provide for the leakage only in the future. The water necessary for lockages is approximately 350 cubic feet per second, allowing twenty minutes for each lockage, a lift of 6 feet, and considering that the lock may be continuously in operation during some periods.

This makes the quantity of water necessary for maintaining navigation about 1,500 cubic feet per second, which, from a flow in the river of 5,500 cubic feet per second, leaves 4,000 second-feet to be diverted for power uses at a river stage of 2 feet or more above low water.

*C.* In determining the location of the water-power plant, but little choice is offered. If built in connection with the lock, it would interfere more or less with the operation of the lock besides involving an excessive construction cost. Another possible location would be in connection with the weir section of the dam, but this is not practicable for it would interfere with the operation of the dam and the plant could hardly withstand the destructive effects of floods and ice. The best location seems to be below the abutment end of the dam, and in Fig. 2 a sketch of a plant to fit this location is shown. Only a general idea of the scheme is given as elementary principles alone were considered, but it is thought the general scheme as shown is the most economical in cost and effective in power.

To allow for the usual length of pass and weirs in the dam, the turbine house is located immediately below the abutment and at the foot of the river bank. The forebay leads from the upper pool just above the dam and is formed by excavating into the river bank. There will be but little loss of head in the conduits leading to and from the turbines, as they are very short.

With a 5-foot head at the plant and 4,000 cubic feet of water




SKETCH SHOWING PROPOSED SCHEME FOR UTILIZATION OF WATER POWER FOR COMMERCIAL PURPOSES AT MOVABLE DAMS ON OHIO RIVER

SCALES: 1" = 20' & 100

Fig. 2.

available per second, as have been previously assumed for this investigation, there would be, theoretically, $\frac{4{,}000 \times 5 \times 62.5}{550} =$ 2,270 horsepower. For producing the power under the low head available, vertical turbines or those having [illegible] wheels on vertical shafts are undoubtedly the most efficient. [illegible]e scheme shown by Fig. 2, eighteen 66-inch vertical turbines of [illegible]lard design are considered, which will develop about 80 per [illegible]f the energy due to

the head of water. Allowing, also, 12.5 per cent for speed regulation, there will remain 2,270 × .80 × .875, or, approximately, 1,600 horsepower at the turbines to be utilized.

It is improbable that the power can be used at the site of its development except in a few locations, and even then not in the same building in which the turbines are placed; for that would require too high and expensive a structure to place the machinery above high water, and the building would also be dangerously exposed to the destructive effects of drift and ice. Therefore, it is proposed to transmit the power mechanically by means of geared shafting or rope drives from the turbines to electric generators in a building higher upon the river bank and safe from floods, drift, and ice.

Allowing 95 per cent efficiency in transmitting the power from the turbines to the dynamos and 92 per cent for the dynamos, there will be 1,600 × .95 × .92, or, approximately, 1,400 horsepower left to be utilized at the site or to be transmitted to other places.

*D.* In estimating the cost of the water power, nothing will be included for the cost of the dams, as the object of their construction is primarily for navigation purposes and the power development will not add anything either for first cost or for operation of the dams.

It is realized that the cost of installing a plant will vary with the locations of the dams due to a difference in foundations, formation of river bank, etc., and in preparing the following estimate of cost the Board has endeavored to use such quantities as would be found at a typical location, giving as much attention to detail as is possible from the general design submitted:

*Forebay, turbine house, etc.:*

| | |
|---|---|
| Excavation | $27,000 |
| Round piling | 12,000 |
| Sheet piling | 17,000 |
| Common timber | 8,000 |
| Riprap | 11,000 |
| Concrete | 101,000 |
| Steel for grillage in floors and roof | 4,000 |
| Head gates and screens | 8,000 |
| Turbines, 18 66-inch | 25,000 |
| Equipment for transmitting the power from turbines to dynamos | 10,000 |
| Power house | 20,000 |
| Dynamos, 1050 K.W. capacity, with auxiliary electrical equipment | 18,000 |
| Total cost of power plant | $261,000 |

As stated on page 31 of this report, in only a few cases can the power be utilized at the site of its development, and to provide for its transmission means not only an increased first cost of the plant but also a loss in the power that can be delivered to the consumer. On account of the distance which the power may have to be transmitted being indeterminate, the cost of the power is estimated as delivered at the dynamos, and also at several points distant from same on the basis that the first cost of a transmission line is $3,000 per mile and the loss in power for the same distance is 1 per cent.

It has been previously determined that the full capacity of the plant can be obtained for an average of one hundred and thirty-nine days, and that for a further twenty-two days per year one-half of the full capacity of the plant will be available. The total power available per annum in units of horsepower-hours will then be $(1,400 \times 139 \times 24) + (700 \times 22 \times 24) = 5,040,000$.

The annual cost of the power is estimated as follows:

*Without transmission line.*

| | |
|---|---|
| Interest on cost of power plant ($261,000), at 4 per cent | $10,440 |
| Depreciation on power house ($20,000), at 1 per cent. | 200 |
| Depreciation on turbine house walls, etc. ($120,000), at 5 per cent | 600 |
| Depreciation on machinery, etc. ($61,000), at 2 per cent. | 1,220 |
| Superintendence and labor | 7,000 |
| Supplies and repairs | 1,000 |
| Total | $20,460 |

*Transmission line only (per mile).*

| | |
|---|---|
| Interest on cost ($3,000), at 4 per cent | $120 |
| Depreciation on line ($3,000), at 2 per cent | 60 |
| Repairs, etc. | 20 |
| Total | $200 |

The unit cost of power is then as follows:

| Location. | Total cost per annum. | Loss of power in transmission. | Power delivered per annum. | Cost per horsepower-hour. |
|---|---|---|---|---|
| | | *Horsepower.* | *Horsepower hours* | |
| At power house | $20,460 | 0 | 5,040,000 | $0.0041 |
| One mile from power house | 20,660 | 14 | 4,989,600 | .0042 |
| Five miles from power house | 21,460 | 70 | 4,788,000 | .0045 |
| Ten miles from power house | 22,460 | 140 | 4,536,000 | .0050 |
| Twenty miles from power house | 24,460 | 280 | 4,032,000 | .0061 |

These costs, as before explained, are based on the development of the power on the Ohio River above the mouth of the Great Kanawha, but there would be no material difference in costs for the small portion of the river below that is within the scope of this report.

Since the cost of the dams is not included, the relative costs of power development above and below that point would be approximately in proportion to the capacities of the plants. The average total time per year of available power would probably be slightly less and the discharge of the river more, below the mouth of the Kanawha River than above, on account of its influence on the Ohio River. The difference in total time of power would not be of much consequence; but in the discharge the increase is considerable, as previously explained in this report. The amount of this increase, though, can not be definitely determined at present as sufficient and reliable discharge data are not available for that portion of the river. For these reasons it is not considered necessary to go into any further consideration of the costs of the water power, which will be approximately the same for all of the river to be considered as shown in previous table.

The high cost of the power is principally due to the fact that the plant is necessarily idle for over half of the year, while the cost of development and operation is not materially reduced on account of the power not being furnished continually.

Besides increasing the actual cost, the intermittent operation of the plant also decreases the value of the power and it is highly improbable that any industry could utilize this power unless it had an auxiliary plant of the same capacity as the water power furnished it. This auxiliary power plant would have to be held continually in readiness for operation on short notice, as the water-power supply may be cut off at any time, due to freshets; therefore, the cost of superintendence and labor for operating the auxiliary plant would be about the same as though it were run continuously, and the only saving due to the use of the water power when available would be the fuel. For this reason it is believed that the value of the water power is not more than the cost of the fuel necessary to produce the same power by some other means.

The territory along the Ohio River in the district under consideration is, in particular, favorably situated with respect to an abundant and cheap supply of fuel, such as coal, natural gas, and petroleum; this also is to the disadvantage of the value of the water power.

Assuming as closely as possible the present market prices of the fuel for the locality, and the amounts of such fuel necessary from the best obtainable data, the following are the estimated costs of power:

| Fuel. | Quantity per horsepower hour. | Unit cost of fuel delivered. | Cost of fuel per horse-power-hour. |
|---|---|---|---|
| Coal in steam plant | 5 pounds | $1.50 per ton | $0.00375 |
| Coal in producer-gas plant | 2 pounds | 1.50 per ton | .0015 |
| Natural gas | 12 cubic feet | .20 per 1,000 cubic feet | .0024 |
| Gasoline | 0.1 gallon | .12 per gallon | .012 |
| Petroleum | 0.125 gallons | .02 per gallon | .0025 |

This table shows the costs of all the kinds of fuel considered to be less for the unit of power than the total cost of the water power as shown in a previous table. It is evident then that the water power can not be developed and furnished in competition with power from other sources on the basis that its value is only that of the fuel it saves, and on which basis it is believed the valuation of the water power must be derived as before explained.

The Board therefore concludes that it is not economical to develop and utilize water power for industrial and commercial purposes in connection with the movable dams on the Ohio River from the Pennsylvania State line to Dam No. 26.

TABLE I.—Showing probable time in days for stages in feet of the Ohio River when the dams, if in operation, would have been up and water power available. Also number of interruptions per year of the water power, caused by lowering the dams on account of freshets, and by periods of extreme low water when there is no water available for power.

| Year. | Interruptions in power. | | Between stages, in feet, above low water. | | | | | | | | Total days available for power. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | By lowering dams. | By low water. | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 | 7–8 | |
| *At Dam No. 6.* | | | | | | | | | | | |
| 1894 | 2 | 2 | See note *a*. | 43 | 24 | 23 | 14 | 20 | 12 | 1 | 137 |
| 1895 | 0 | 3 | | 57 | 51 | 28 | 23 | 17 | 6 | 6 | 189 |
| 1896 | 5 | 0 | | 18 | 19 | 25 | 34 | 23 | 23 | 10 | 152 |
| 1897 | 3 | 2 | | 19 | 26 | 28 | 22 | 19 | 13 | 5 | 137 |
| 1898 | 6 | 0 | | 40 | 33 | 27 | 21 | 27 | 11 | 14 | 173 |
| 1899 | 1 | 1 | | 52 | 25 | 36 | 32 | 43 | 21 | 14 | 223 |
| 1900 | 1 | 1 | | 49 | 40 | 35 | 40 | 20 | 10 | 8 | 202 |
| 1901 | 1 | 0 | | 47 | 27 | 21 | 20 | 15 | 16 | 8 | 154 |
| 1902 | 4 | 0 | | 29 | 46 | 20 | 35 | 16 | 19 | 14 | 179 |
| 1903 | 5 | 0 | | 4 | 51 | 47 | 41 | 36 | 17 | 15 | 211 |
| 1904 | 3 | 0 | | 76 | 40 | 39 | 14 | 19 | 11 | 3 | 202 |
| 1905 | 7 | 0 | | 0 | 21 | 11 | 32 | 45 | 30 | 20 | 159 |
| 1906 | 4 | 0 | | 3 | 31 | 39 | 33 | 30 | 29 | 16 | 181 |
| 1907 | 3 | 0 | | 0 | 11 | 21 | 38 | 25 | 26 | 25 | 146 |
| 1908 | 0 | 1 | | 19 | 16 | 40 | 9 | 6 | 8 | 4 | 102 |
| Averages | 3 | 0.7 | | 30 | 31 | 29 | 27 | 24 | 17 | 11 | 170 |
| *At Dam No. 8.* | | | | | | | | | | | |
| 1905 | 8 | 0 | See note *a*. | 2 | 17 | 8 | 33 | 54 | 39 | 8 | 161 |
| 1906 | 4 | 0 | | 6 | 25 | 44 | 30 | 35 | 24 | 17 | 181 |
| 1907 | 3 | 0 | | --- | 11 | 22 | 37 | 25 | 25 | 23 | 143 |
| 1908 | 0 | 1 | | 18 | 18 | 32 | 19 | 7 | 5 | 4 | 103 |
| Averages | 3.7 | 0.3 | | 7 | 18 | 27 | 30 | 30 | 23 | 13 | 147 |
| *At Dam No. 11.* | | | | | | | | | | | |
| 1905 | 8 | 0 | See note *a*. | 0 | 21 | 16 | 33 | 48 | 24 | 28 | 170 |
| 1906 | 4 | 0 | | 5 | 33 | 44 | 27 | 26 | 22 | 14 | 171 |
| 1907 | 2 | 0 | | 1 | 12 | 32 | 32 | 26 | 18 | 21 | 142 |
| 1908 | 0 | 1 | | 18 | 33 | 25 | 9 | 9 | 6 | 3 | 103 |
| Averages | 3.2 | 0.3 | | 6 | 25 | 29 | 25 | 27 | 18 | 17 | 146 |
| *At Dam No. 13.* | | | | | | | | | | | |
| 1902 | 3 | ------ | See note *a*. | 31 | 38 | 22 | 27 | 20 | 7 | 15 | 160 |
| 1903 | 5 | ------ | | 6 | 49 | 58 | 37 | 22 | 10 | 13 | 195 |
| 1904 | 2 | ------ | | 84 | 40 | 29 | 13 | 18 | 5 | ---- | 189 |
| 1905 | 6 | ------ | | --- | 18 | 10 | 30 | 37 | 20 | 32 | 147 |
| 1906 | 4 | ------ | | 3 | 34 | 39 | 32 | 24 | 19 | 22 | 173 |
| 1907 | 2 | ------ | | --- | 9 | 21 | 37 | 23 | 24 | 28 | 142 |
| 1908 | --------- | 1 | | 15 | 24 | 26 | 18 | 7 | 7 | 3 | 100 |
| Averages | 3.1 | 0.1 | | 20 | 30 | 29 | 28 | 22 | 13 | 16 | 158 |
| *At Dam No. 18.* | | | | | | | | | | | |
| 1903 | 2 | ------ | See note *a*. | 22 | 45 | 45 | 21 | 26 | 27 | 29 | 215 |
| 1904 | 2 | ------ | | 101 | 41 | 14 | 11 | 19 | 3 | ---- | 189 |
| 1905 | 6 | ------ | | --- | 22 | 9 | 26 | 34 | 19 | 27 | 137 |
| 1906 | 4 | ------ | | 4 | 37 | 27 | 43 | 30 | 21 | 7 | 169 |
| 1907 | 2 | ------ | | --- | 10 | 21 | 38 | 28 | 21 | 25 | 143 |
| 1908 | --------- | 1 | | 23 | 21 | 34 | 14 | 11 | 5 | 3 | 111 |
| Averages | 2.7 | 0.2 | | 25 | 29 | 25 | 26 | 25 | 16 | 15 | 161 |

TABLE I.—*Continued.*

| Year. | Interruptions in power. | | Between stages, in feet, above low water. | | | | | | | | Total days available for power. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | By lowering dams. | By low water. | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | |
| *Below mouth of Great Kanawha River.* | | | | | | | | | | | |
| 1899 | 1 | See note *b*. | 0 | 53 | 24 | 45 | 27 | 11 | 16 | 1 | 177 |
| 1900 | 3 | | 39 | 22 | 29 | 24 | 46 | 18 | 5 | 13 | 196 |
| 1901 | 2 | | 0 | 22 | 21 | 17 | 17 | 12 | 12 | 19 | 120 |
| 1902 | 2 | | 9 | 44 | 25 | 16 | 25 | 18 | 4 | 6 | 149 |
| 1903 | 3 | | 0 | 45 | 41 | 33 | 15 | 20 | 25 | 24 | 203 |
| 1904 | 2 | | 63 | 61 | 25 | 3 | 13 | 12 | 6 | 4 | 187 |
| 1905 | 4 | | 0 | 0 | 0 | 25 | 5 | 37 | 25 | 19 | 111 |
| 1906 | 3 | | 0 | 0 | 4 | 29 | 32 | 23 | 28 | 19 | 135 |
| 1907 | 5 | | 0 | 0 | 0 | 10 | 29 | 17 | 15 | 2 | 73 |
| 1908 | 1 | | 33 | 52 | 15 | 23 | 34 | 21 | 4 | 4 | 186 |
| Averages | 2.6 | | 14 | 17 | 18 | 23 | 24 | 19 | 14 | 11 | 158 |

Note *a*. Above mouth of Great Kanawha River there is no water available for power when river is less than 1 foot above low water.

Note *b*. Below mouth of Great Kanawha River water is available for power at low water stages.

TABLE II.—Summary of averages in Table I, and general averages of the duration in days per year of the different stages for all the locations considered.

| Stages above low water in feet. | Dam No. 6. 1894 to 1908. | Dam No. 8. 1905 to 1908. | Dam No. 11. 1905 to 1909. | Dam No. 13. 1902 to 1908. | Dam No. 18. 1903 to 1908. | Below mouth of Great Kanawha River. | Averages | Total time of power for each stage or over. |
|---|---|---|---|---|---|---|---|---|
| 0 to 1 | ------ | ------ | *a* | *a* | ------ | 14 | *b* | ------ |
| 1 to 2 | 30 | 7 | 6 | 20 | 25 | 17 | 22 | 161 |
| 2 to 3 | 31 | 18 | 25 | 30 | 29 | 18 | 28 | 139 |
| 3 to 4 | 29 | 27 | 29 | 29 | 25 | 23 | 28 | 111 |
| 4 to 5 | 27 | 30 | 25 | 28 | 26 | 24 | 27 | 83 |
| 5 to 6 | 24 | 30 | 27 | 22 | 25 | 19 | 25 | 56 |
| 6 to 7 | 17 | 23 | 18 | 13 | 16 | 14 | 17 | 31 |
| 7 to 8 | 11 | 13 | 17 | 16 | 15 | 11 | 14 | 14 |
| *Number of interruptions per year in water power.* | | | | | | | | |
| By lowering dams | 3.0 | 3.7 | 3.2 | 3.1 | 2.7 | 2.6 | 3.1 | ------ |
| By low water | 0.7 | 0.3 | 0.3 | 0.1 | 0.2 | ------- | 0.4 | ------ |

Note *a*. Above mouth of Great Kanawha River there is no water available for power when river is less than 1 foot above low water.

Note *b*. The data for below the mouth of the Great Kanawha River are not included in obtaining the above averages on account of a comparatively large increase in the discharge of the Ohio at that point.

Also, since at locations below Dam No. 6 data were obtainable for recent years only, and since the greater number of these years were either extremely wet or dry, the results given in column for averages were obtained by giving to each location a weight in proportion to the number of years in which the stages are shown in Table I.

TABLE III.—Maneuvers at the Davis Island Dam.

| Year. | Raised. | 8 a. m. stage. | Lowered. | 8 a. m. stage. | No. of days up. | Remarks. |
|---|---|---|---|---|---|---|
| 1885 | Oct. 7 | 1.9 | Oct. 14 | 4.4 | 7 | First time up. |
| 1886 | June 5 | 3.66 | June 17 | 4.5 | 12 | |
| | June 26 | 5.66 | June 26 | 5.66 | 1 | |
| | July 5 | 3.25 | Aug. 2 | 5.41 | 28 | |
| | Sept. 1 | 2.66 | Nov. 14 | 7.25 | 75 | |
| Total | | | | | 116 | |
| 1887 | Apr. 12 | 4.58 | Apr. 18 | 6.25 | 6 | |
| | June 6 | 5.0 | June 7 | 4.92 | 1 | |
| | June 28 | 2.75 | | | 186 | |
| Total | | | | | 193 | |
| 1888 | | | Jan. 3 | 9.16 | 3 | |
| | June 18 | 4.33 | July 10 | 7.58 | 22 | |
| | July 28 | 3.25 | Aug. 19 | 5.5 | 22 | |
| | Sept. 8 | 3.75 | Sept. 10 | 9.75 | 2 | Partly up. |
| | Sept. 16 | 4.25 | Oct. 8 | 5.41 | 22 | |
| Total | | | | | 71 | |
| 1889 | Sept. 2 | 2.0 | Oct. 22 | 3.4 | 50 | |
| 1890 | July 14 | 3.1 | Aug. 27 | 8.3 | 44 | |
| | Sept. 3 | 4.5 | Sept. 7 | 4.9 | 4 | |
| Total | | | | | 48 | |
| 1891 | May 8 | 4.0 | June 27 | 5.9 | 30 | |
| | June 16 | 4.4 | June 19 | 6.8 | 4 | |
| | June 30 | 4.6 | July 8 | 5.8 | 8 | |
| | July 15 | 4.8 | July 24 | 5.1 | 14 | |
| | Aug. 10 | 4.5 | Aug. 24 | 7.1 | 14 | |
| | Sept. 2 | 4.3 | Nov. 24 | 8.5 | 83 | |
| Total | | | | | 153 | |
| 1892 | July 1 | 5.3 | July 3 | 5.7 | 2 | |
| | July 11 | 4.1 | Dec. 2 | 5.8 | 144 | |
| Total | | | | | 146 | |
| 1893 | June 13 | 3.7 | Nov. 30 | 8.0 | 200 | |
| 1894 | May 14 | 4.5 | May 18 | 4.9 | 4 | |
| | June 15 | 4.4 | Sept. 20 | 6.3 | 99 | |
| | Sept. 28 | 3.6 | Dec. 2 | 5.4 | 65 | |
| Total | | | | | 168 | |
| 1895 | May 2 | 4.5 | Nov. 27 | 7.9 | 208 | |
| 1896 | May 12 | 4.3 | June 25 | 6.5 | 44 | |
| | July 2 | 4.7 | July 16 | 8.5 | 14 | |
| | Aug. 18 | 4.0 | Sept. 30 | 4.6 | 42 | |
| | Oct. 9 | 5.0 | Oct. 15 | 6.8 | 6 | |
| | Oct. 31 | 5.0 | Nov. 6 | 6.4 | 6 | |
| Total | | | | | 112 | |
| 1897 | June 12 | 4.7 | July 20 | 6.1 | 38 | |
| | Aug. 4 | 4.7 | Aug. 18 | 6.3 | 14 | |
| | Aug. 21 | 4.9 | Nov. 16 | 5.8 | 87 | |
| | Nov. 23 | 4.7 | Nov. 27 | 4.5 | 4 | |
| Total | | | | | 143 | |

TABLE III—*Continued.*

| Year. | Raised. | 8 a. m. stage. | Lowered. | 8 a. m. stage. | No. of days up. | Remarks. |
|---|---|---|---|---|---|---|
| 1898 | June 2 | 5.5 | June 15 | 6.7 | 13 | |
| | June 17 | 5.0 | Aug. 6 | 9.0 | 50 | |
| | Aug. 26 | 5.4 | Oct. 21 | 6.8 | 56 | |
| | Nov. 3 | 5.4 | Nov. 7 | 6.0 | 4 | |
| Total | | | | | 123 | |
| 1899 | May 28 | 4.9 | May 31 | 7.1 | 3 | |
| | June 8 | 5.0 | July 18 | 6.8 | 40 | |
| | July 23 | 4.1 | Dec. 12 | 5.5 | 142 | |
| Total | | | | | 185 | |
| 1900 | May 12 | 4.4 | June 10 | 3.9 | 37 | |
| | June 23 | 4.0 | Nov. 23 | 7.5 | 153 | |
| Total | | | | | 190 | |
| 1901 | Jan. 10 | 4.3 | Jan. 11 | 5.5 | 1 | Lowered by steamboat. |
| | July 15 | 3.0 | Sept. 17 | 6.4 | 64 | |
| | Sept. 22 | 5.2 | Nov. 24 | 4.1 | 63 | |
| Total | | | | | 128 | |
| 1902 | May 1 | 5.6 | May 5 | 6.8 | 5 | |
| | May 12 | 5.4 | June 30 | 6.0 | 50 | |
| | July 18 | 5.1 | July 21 | 7.0 | 3 | |
| | Aug. 7 | 5.6 | Oct. 12 | 6.0 | 66 | |
| | Oct. 16 | 5.7 | Nov. 26 | 3.8 | 41 | |
| | Dec. 2 | 5.4 | Dec. 3 | 5.8 | 1 | |
| Total | | | | | 166 | |
| 1903 | May 2 | 4.7 | May 28 | 7.0 | 26 | |
| | May 30 | 5.4 | June 14 | 5.5 | 17 | |
| | June 18 | 6.4 | June 23 | 8.0 | 5 | |
| | July 16 | 6.3 | July 19 | 5.3 | 4 | |
| | July 26 | 5.3 | Aug. 28 | 5.3 | 34 | |
| | Sept. 5 | 5.2 | Oct. 9 | 6.2 | 45 | |
| | Oct. 14 | 5.3 | Nov. 17 | 5.2 | 35 | |
| | Nov. 26 | 5.6 | Dec. 4 | 3.8 | 8 | |
| | Dec. 5 | 3.6 | Dec. 20 | 3.5 | 15 | |
| Total | | | | | 189 | |
| 1904 | May 11 | 5.5 | May 18 | 5.7 | 8 | |
| | June 13 | 5.7 | July 7 | 5.7 | 24 | |
| | July 18 | 5.2 | Dec. 25 | 2.4 | 164 | |
| Total | | | | | 196 | |
| 1905 | May 4 | 5.5 | May 12 | 5.9 | 8 | |
| | May 22 | 6.0 | June 8 | 8.0 | 17 | |
| | June 16 | 5.0 | June 19 | 6.4 | 3 | |
| | June 30 | 5.7 | July 8 | 6.8 | 8 | |
| | July 19 | 4.9 | July 30 | 4.3 | 11 | |
| | Aug. 4 | 5.1 | Aug. 16 | 8.2 | 12 | |
| | Aug. 20 | 5.4 | Sept. 12 | 8.2 | 23 | |
| | Sept. 16 | 5.0 | Oct. 20 | 5.5 | 33 | |
| | Oct. 31 | 5.1 | Nov. 29 | 6.2 | 29 | |
| Total | | | | | 144 | |

TABLE III—*Continued.*

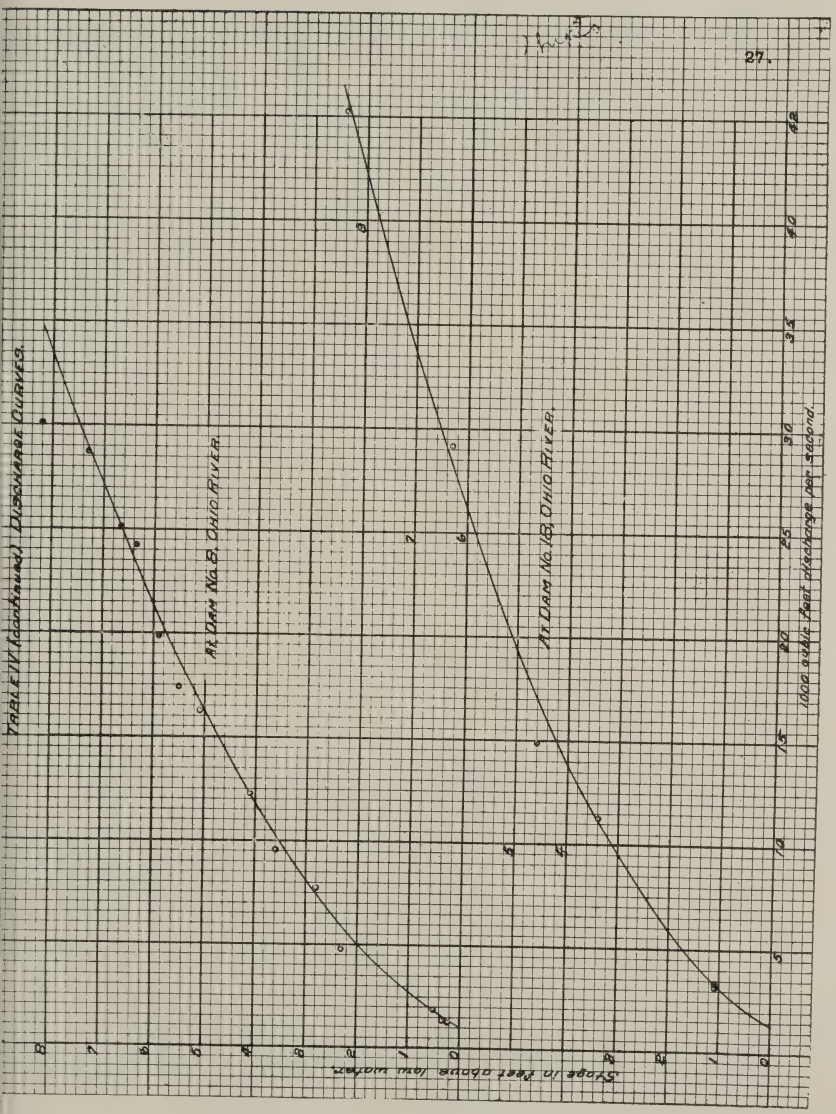
| Year. | Raised. | 8 a. m. stage. | Lowered. | 8 a. m. stage. | No. of days up. | Remarks. |
|---|---|---|---|---|---|---|
| 1906 | May 16 | 5.2 | June 7 | 4.7 | 22 | |
| | June 12 | 5.7 | Aug. 10 | 9.2 | 59 | |
| | Aug. 15 | 5.6 | Aug. 20 | 7.4 | 4 | |
| | Aug. 26 | 5.6 | Nov. 19 | 6.3 | 85 | |
| | Dec. 1 | 5.2 | Dec. 7 | 9.2 | 7 | |
| Total | | | | | 177 | |
| 1907 | June 26 | 5.3 | July 3 | 7.5 | 7 | |
| | July 6 | 5.8 | July 12 | 8.8 | 6 | |
| | July 17 | 5.7 | July 17 | 5.7 | | Up 1 hour 10 minutes. |
| | July 30 | 5.5 | Aug. 25 | 9.0 | 26 | |
| | Aug. 29 | 4.5 | Sept. 12 | 8.9 | 14 | |
| | Sept. 15 | 5.0 | Oct. 6 | 7.2 | 21 | |
| | Oct. 14 | 5.5 | Oct. 29 | 7.2 | 15 | |
| | Nov. 16 | 5.9 | Nov. 25 | 8.2 | 9 | |
| | Dec. 2 | 6.0 | Dec. 11 | 7.8 | 9 | |
| Total | | | | | 107 | |
| 1908 | June 10 | 4.9 | Jan. 6, 1909 | 9.5 | 211 | |

TABLE IV.—Discharges of the Ohio River determined between Dams No. 6 and 26.

| Date of measurement. | Location. | Stage above low water. | Mean velocity second feet. | Area of section square feet. | Discharge cubic feet per second. | River. |
|---|---|---|---|---|---|---|
| | *Near Dam No. 6—determined by U.S. Engineer Department* | | | | | |
| Sept. 14, 1908 | 800 ft. below dam | 0.6 | 1.35 | 1,307 | 1,767 | Stationary. |
| Sept. 14, 1908 | 1,200 ft. below dam | 0.6 | 1.02 | 1,722 | 1,765 | Do. |
| Sept. 24, 1908 | 700 ft. below dam | 0.0 | 0.82 | 1,343 | 1,102 | Do. |
| Sept. 24, 1908 | 1,200 ft. below dam | 0.0 | 0.94 | 1,272 | 1,202 | Do. |
| | *Near Dam No. 8—determined by U.S. Engineer Department.* | | | | | |
| Oct. 5, 1905 | From 300 to 1,000 feet above upper end of upper guide wall of lock. | 3.6 | 1.00 | 9,538 | 9,518 | Rising slowly. |
| Oct. 9, 1905 | ----do---- | 2.3 | 0.60 | 8,155 | 4,853*a* | Falling slowly. |
| Oct. 16, 1905 | ----do---- | 5.9 | 1.66 | 11,992 | 19,930 | Do. |
| Oct. 25, 1905 | ----do---- | 8.2 | 2.08 | 14,448 | 30,058*a* | Do. |
| June 9, 1908 | ----do---- | 5.5 | 1.60 | 10,919 | 17,460 | Do. |
| June 10, 1908 | ----do---- | 5.1 | 1.58 | 10,266 | 16,203 | Do. |
| June 13, 1908 | ----do---- | 4.1 | 1.29 | 9,467 | 12,242 | Do. |
| July 1, 1908 | ----do---- | 2.8 | 0.99 | 7,820 | 7,750 | Do. |
| July 23, 1908 | ----do---- | 6.65 | 1.98 | 12,635 | 25,060 | Do. |
| July 24, 1908 | ----do---- | 6.35 | 1.97 | 12,344 | 24,280 | Do. |
| July 27, 1908 | ----do---- | 7.3 | 2.16 | 13,297 | 28,741 | Stationary. |
| Sept. 5, 1908 | Opposite coffer dam for first section of pass. Coffer dam across lock. | 0.35 | 0.32 | 4,332 | 1,379 | Do. |

| Date of measurement. | Location. | Stage above low water. | Mean velocity second feet. | Area of section square feet. | Discharge cubic feet per second. | River. |
|---|---|---|---|---|---|---|
| | *Near Dam No. 8*—Con.* | | | | | |
| Sept. 17, 1908 | In narrow channel | 0.50 | 1.44 | 1,264 | 1,828 | Stationary. |
| | opposite lower end of Wellsville. | 0.23 | 1.04 | 1,184 | 1,237 | Do. |
| | *At Wheeling.*† | | | | | |
| Prior to 1893 *b* | At steel trolley and highway bridges opposite city. | 8.50 | ------ | ------- | 36,260 | |
| Mar. 14, 1905 | ----do---------- | 14.35 | 4.10 | 19,920 | 81,740 | |
| Mar. 14, 1905 | ----do---------- | 13.94 | 4.01 | 19,300 | 77,440 | |
| Mar. 15, 1905 | ----do---------- | 12.37 | 3.80 | 17,410 | 66,280 | |
| Mar. 17, 1905 | ----do---------- | 10.43 | 3.45 | 15,040 | 51,850 | |
| Mar. 20, 1905 | ----do---------- | 28.20 | 5.89 | 38,890 | 229,200 | |
| Mar. 20, 1905 | ----do---------- | 30.80 | 6.13 | 42,750 | 261,900 | |
| Mar. 21, 1905 | ----do---------- | 38.90 | 6.23 | 54,780 | 341,100 | |
| Mar. 21, 1905 | ----do---------- | 40.70 | 6.18 | 57,360 | 354,400 | |
| Mar. 22, 1905 | ----do---------- | 42.05 | 6.07 | 59,580 | 361,600 | |
| Mar. 22, 1905 | ----do---------- | 42.50 | 6.05 | 60,510 | 365,700 | |
| Mar. 23, 1905 | ----do---------- | 41.60 | 5.73 | 58,830 | 336,900 | |
| Mar. 23, 1905 | ----do---------- | 40.30 | 5.60 | 56,790 | 318,100 | |
| Mar. 24, 1905 | ----do---------- | 35.20 | 5.20 | 49,250 | 255,800 | |
| Mar. 24, 1905 | ----do---------- | 32.70 | 4.99 | 45,550 | 227,300 | |
| Mar. 25, 1905 | ----do---------- | 27.20 | 4.95 | 37,560 | 186,100 | |
| Mar. 25, 1905 | ----do---------- | 25.50 | 4.80 | 35,050 | 168,100 | |
| Mar. 27, 1905 | ----do---------- | 22.44 | 4.83 | 30,830 | 149,100 | |
| Apr. 13, 1905 | ----do---------- | 13.06 | 3.65 | 18,700 | 68,380 | |
| Apr. 19, 1905 | ----do---------- | 7.51 | 2.46 | 11,710 | 28,760 | |
| Apr. 21, 1905 | ----do---------- | 7.35 | 2.44 | 11,490 | 27,990 | |
| June 1, 1905 | ----do---------- | 5.20 | 1.62 | 9,054 | 14,640 | |
| Aug. 25, 1905 | ----do---------- | 5.78 | 1.84 | 9,799 | 18,040 | |
| Aug. 28, 1905 | ----do---------- | 7.78 | 2.56 | 12,310 | 31,500 | |
| Nov. 1, 1905 | ----do---------- | 6.20 | 1.93 | 10,270 | 19,800 | |
| May 22, 1906 | ----do---------- | 5.70 | 1.76 | 9,880 | 17,400 | |
| | *Near Dam No. 18.** | | | | | |
| Oct. 15, 1892 | 1½ miles below mouth of Muskingum River. | 1.10 | 0.35 | 9,165 | 3,195*a* | |
| Oct. 17, 1892 | ----do---------- | 1.10 | 0.36 | 9,200 | 3,315*a* | |
| 1903 | About 1,000 feet above Dam No. 18 | 3.4 | ------ | ------- | 11,265 | |
| 1903 | ----do---------- | 4.6 | ------ | ------- | 14,984 | |
| 1903 | ----do---------- | 6.3 | ------ | ------- | 29,205 | |
| 1903 | ----do---------- | 8.4 | ------ | ------- | 42,264 | |
| 1903 | ----do---------- | 10.7 | ------ | ------- | 61,241 | |
| | *Below mouth of Great Kanawha River.** | | | | | |
| Oct. 20, 1892 | 3½ miles below mouth of Great Kanawha River. | 10.80 | 0.97 | 5,797 | 5,652*a* | |
| Oct. 21, 1892 | ----do---------- | 0.75 | 1.02 | 5,759 | 5,842*a* | |
| Oct. 21, 1892 | ----do---------- | 0.75 | 0.96 | 5,679 | 5,467*a* | |
| Oct. 9, 1908 | 600 feet above Dam No. 26. | 0.3 | ------ | ------- | 5,100 | |
| Oct. 13, 1908 | ----do---------- | 3.0 | ------ | ------- | 18,500 | |
| Nov. 19, 1908 | ----do---------- | 1.6 | ------ | ------- | 6,400 | |
| Dec. 3, 1908 | ----do---------- | 1.5 | ------ | ------- | 7,300 | |
| Dec. 7, 1908 | ----do---------- | 1.8 | ------ | ------- | 8,600 | |

Note *a*. Discharge too small; see curve at end of this table. †Determined by U. S. Geological Survey from Report of Progress of Stream Measurements for 1905. Note *b*. Measurement made by U. S. Weather Bureau. *Determined by U. S. Engineer Department.


27.
Table IV. (Goodhue) Discharge Curves.
At Dam No. 8, Ohio River.
At Dam No. 18, Ohio River.
Slope in feet above low water.
1000 cubic feet discharge per second.

# Is The Engineer School Necessary?

*BY*

Maj. R. R. Raymond
*Corps of Engineers*

A doubt having been expressed informally as to the usefulness of the Engineer School, or any service school, a few thoughts on the subject may not be amiss. This paper does not pretend to cover the whole question or to settle any part of it. It simply throws a few side lights on the matter.

When there is work of any kind to be done, it will be done best and most economically by a man who is properly equipped and trained for the purpose. This may be accepted as axiomatic; but to emphasize the point, as well as to determine what constitutes proper equipment and training, let us take a simple illustration.

You wish to have a set of shelves built in your office. You summon a carpenter, who comes and examines the contemplated job, gives you an estimate on it, goes and gets the necessary tools and material, and in a reasonable time completes the work. You find that your shelves present a neat appearance and show good workmanship. You are satisfied and pleased with the workman. You care nothing whatever about his ability as a mathematician, a writer, a theologian, or even an engineer. So far as your wants are concerned, he is a trained (that is, an educated) man. A friend drops in and tells you that he wishes you to recommend a carpenter to build him a cupboard. You reply that you know a man who has just made a good job of a set of shelves. You have never seen him build a cupboard, but you feel sure that he has the necessary tools and skill to do so, and you confidently recommend him for the higher job.

Now this seems to be a very simple and sensible proceeding. There is nothing at all remarkable about it. Anyone has sense enough to do the same thing. The same rule applies in all the walks of life. But does it? Do we select our trained men for the work of the Army in this sensible way? Do we not proceed more as follows:

The carpenter arrives with nothing in his hands. We are aston-

ished at this, and we ask if he has no hammer. He replies that it is in his tool chest, where it belongs. Dear, dear! it should be somewhere on his person. Has he no saws, no planes, no square, no screwdriver, no chisels, etc.? He says that he has, but they also are in their proper places in the tool chest. We are grieved at this and fear that he is not properly equipped for the work in hand. Then, too, a friend of ours intends to build a cupboard which will involve the use of beading and molding. Has the carpenter the special tools for this? Has he a mortising machine? Why, no; certainly not. If he fills his chest with tools which are of infrequent use, he only makes it the more difficult to get at the more important tools in the chest; and, besides, it is more economical to have such work done at the mill. We fear that we can not employ him, as he is not provided with all the tools required to meet possible needs. In vain he points out that when special cases arise he has sense and knowledge enough to go and buy the proper tools, and that if he were to carry upon his person all kinds of tools used in his business he would only crush himself to the earth and be unable to perform any work at all. But no; he is not fully equipped. We can not accept him.

This may appear to be overdrawn; but it is a close parallel to what is done in the Army. Not two years ago the writer was ordered to report to a board for examination to determine his fitness for promotion. He began at once to prepare for the ordeal. How did he go to work? By inviting attention to the shelves he had built? Not at all. He made lists of all the tools which the board in similar cases had insisted should be carried upon the persons of all carpenters who aspired to the construction of cupboards, and he proceeded to attach them to himself for the inspection of the board. (Observe, please, that *facts* and *knowledge* are the tools of the engineer, just as woodworking implements are the tools of the carpenter.) Many tools fell off daily, but he hastily hung them on again, until on the appointed day he presented himself for inspection with the most absurd, ridiculous, and preposterous assortment of tools imaginable heaped upon him and dangling from all his parts. Owing to distance, the board could not inspect him in person, but prepared a list of tools which he was to exhibit and describe under the direction of a designated officer, and which were to be accepted as representing the whole museum. (In other words,

the examination was written.) For ten long weary days he exhibited and described the tools demanded. They formed but a small part of the collection that he had assembled and under whose weight he was barely able to stagger and entirely unable to work. At last the exhibition was over. The board solemnly pronounced him properly equipped to build cupboards. As a matter of fact he could not have built a cupboard then to save him. The load he had borne was too great and the exhaustion too severe. He threw away his burden, confident that most of it would never again be needed and that the rest could be picked up again when desired; but it was several weeks before he had recovered sufficiently to build as good a cupboard as he could have built before he overtaxed his back. There is nothing unusual about this case. It is perfectly typical.

Right here is the proper place for the reader to ask how it is possible, then, to be sure that a man has the proper education for his position. How can a military engineer be trained if he does not acquire all the tools of his profession and keep them always at hand?

To answer this question, let us again consider the carpenter. How did he acquire the skill which enabled him to make a good job of the shelves? Without doubt he began work in his youth under the guidance of an older and more experienced man. By seeing how this preceptor performed his work, he learned to do likewise. He also learned by experience just what tools it was best to keep always available in his tool chest, and how to keep them in the best condition for use. His tools were always a means to an end, never the end itself. Being a man of character, and ambitious, he applied his inventive faculty to improving upon the methods of his teacher, and he naturally became interested in the ideas of others bearing upon his trade. He was familiar with the various special tools which he saw in the hardware store or illustrated in catalogues, and he knew where to obtain such tools in case of need. There could be no question as to his ability to use them, for the knack of using tools is not confined to those alone which are most frequently used. He thus trained himself to perform not only those works which were of daily occurrence, but also those which demanded resourcefulness. The moral is that the ability to do work is acquired by doing it; and doing simple work stimulates the worker and assists him to advance to higher undertakings. No amount of study and theory will produce this result.

Were it possible to take those graduates of the Military Academy

who are assigned to the Corps of Engineers and place them at once under the care of older officers on works where they could see how the tools of the profession should be used, and where they could themselves acquire the use of those tools; or, were it possible, to assign them to companies under experienced captains where they could acquire all the tools of the military branch of their profession; this would produce more efficient officers for both military and civil engineering duties than any amount of instruction in the best equipped school.

Again the reader bobs up with an inquiry as to why this is not done. Why equip and maintain an expensive Engineer School if it is not the best way to train our officers?

The answer is prompt. It is the best way *available*. We are actually sending the young officers to duty under experienced men, but a year is about the longest time that can be spared, and is too short. We have too few officers to assign the young ones for several years to works already properly administered by older men. In many cases the young and inexperienced must control without the guidance of the experienced. Under present conditions, our captains are themselves inexperienced and but little older than their lieutenants. That they acquit themselves as well as they do is highly creditable to them; but they are not old enough to undertake the training of young officers, and the system falls to the ground.

Let us suppose that our young carpenter finds himself at the outset called to a place far removed from the experienced man who was to have trained him. What can the latter do to increase the young man's chances of success? He would probably assist him to select an assortment of those tools which he should always have in his kit, at the same time giving such advice as to their use as the time would permit; and he would give him a catalogue of special tools which he could order later if necessary. This instruction would be very different from the full training which was to have been given, but the young man would go out into the world much better equipped than if he had been left entirely to his own resources. If he is the right kind he will succeed anyway, but starting him on the right road makes his success easier and more certain.

The function of the Engineer School should be exactly similar. The burdens of the Corps of Engineers are steadily increasing, while the time available for the preliminary training of young officers is as steadily decreasing. A few years ago it was three years, and it was then rarely broken into. Now it is only two

years, and the students are assigned to all kinds of duties that interfere with their school work or interrupt it entirely. To-day a young officer is apt, nay quite sure, to be entrusted with important duties. If he knows what tools to use, he will be less apt to make mistakes. If he is the right kind, and most of them are, he will make good anyway; but he will succeed more surely and with less effort if he is given a proper start like the young carpenter. Mistakes in modern engineering are very costly, and good sense demands that every possible precaution be taken against them. If allowed to perform its proper function, the Engineer School is of the highest value, practically indispensable.

The great danger to this School and to the Army is thought to be the tendency toward the belief that the education of the Army is in itself an important thing, whereas it is really of no importance whatever except in so far as it enables the Army to do its work better; and that keeping the Army always at school is the same thing as educating it. At the Engineer School we should give to the student officer the kit of tools which he will need for everyday use, show and explain the more intricate tools which he *may* have to use in special circumstances and tell him how to get these special tools, and then send him out into the life of the Service to make good through his own character and energy. The business of life is work and accomplishment. A certain amount of preparation is wise and necessary; too much is a waste. A man could spend his whole life in the endeavor to learn everything bearing upon his profession, and at the end of that life find that his object had failed and that he had accomplished nothing useful. Not only is this true, but after a certain amount of preparation, the power to use the acquired knowledge is lost. Just as the carpenter who attempts to carry his kit all the time can do little work under such a burden, so the professional man can overload his brain so that it can not work. The musician who practises too much may become paralyzed. The athlete who trains too much may become stale. The student who attempts to learn too much may injure his mind. The same rule holds true in everything.

The whole Army is now at school to the great detriment of its proper work. If every man is able to do his work, and does it, what more can be asked? Why is it necessary that every private shall be trained to be an officer and every officer a general? What can be more appropriate than that every captain shall be engaged in training his company or troop and preparing it for service? This

is a work that demands *all* the intelligence, energy, and time of an able man. How many captains are permitted to do it, however? Are they not rather preparing themselves to be generals? What is wrong with the Army? This is the oft repeated cry. The answer comes: There is nothing wrong with the Army; it was never more efficient than at present. This sounds well, but it is not true. There *is* something wrong. Everyone feels it, this spirit of unrest. The trouble is that we are staggering under our kit of tools and are not doing our work. What is worse, we are losing the power to do it. Would it not be wiser to take the Army out of perpetual school, put it on its own job without distraction, let it learn to use its tools through use and not by holding them up for inspection? Only then will it be a happy and contented Army and a truly educated and efficient one.

Under no circumstances should a company officer be taken away from his company, nor should he be nagged by any school or duties not directly connected with his command. Every particle of his energy is needed to instruct and care for his men. This is the highest and most important duty of a captain. It is recognized in the Army Regulations, but is not in practice accorded its real weight. When the company goes into the field, which is the more important, that the captain shall be qualified to command the regiment (theoretically) or that the company shall do its work? If the captain spends two or three years detached from his command, listens to lectures, rides over historic battlefields, exhausts his energies in study, and learns to think himself IT, how doth it profit the company? How many companies and troops are to-day captainless while their captains are at school?

Should we abolish the schools then? Not at all. They are very valuable if kept in their proper places; but it should never be forgotten that they are a means only. They are of absolutely no importance in themselves. A few officers can well be employed in recording, compiling, and publishing the advances in military science; but it will rarely be the case that any advance comes from an officer on duty at a school. This is not his fault; his brain has no opportunity for original work. The most certain way to prevent a man from inventing anything useful is to keep him busy with matters other than the problem in hand.

These observations apply to all arms of the service, but just now we are especially concerned with their application to the Corps of Engineers. We need trained officers. To train them we must

occupy them with their own work and as little else as possible. Experience is by far the best of all teachers, but, unfortunately, we are expected to be trained in a field that is broader than any one man's experience can possibly be. The Engineer School comes to our rescue here; but to be of real value it should give each man his outfit of knowledge and send him out to real life in the least practicable time. He needs a working equipment and not an encyclopædic education. To give him this equipment quickly, so as to secure to the Government the benefit of his useful services, the School should have every facility. Its instructors should be allowed to perform their functions without other duties. This is now provided for on paper, but the powers that be respect it not at all. The School should have adequate buildings where the laboratories, model rooms, and library could be worked to their utmost capacity. An hour in a model room, such as we could have at the Engineer School, is worth weeks of hard reading. With half a show we could have a school that would really fit our young officers for their life work. Under present conditions it may be doubted whether the results justify the effort. Both instructors and students are overloaded with extraneous duties, or whisked away entirely for all kinds of jobs. The classes are not permitted to progress together throughout the course, but are broken up so that the members graduate months (sometimes years) apart. The Engineer troops are sacrificed by taking their officers away to attend the School, and then the School is disabled by sending its instructors and students to duty with the troops. We are trying to serve two masters, each of whom independently expects to have all our time and energy.

The Engineer troops are a vitally important part of the Army. They should have their full complement of officers and every opportunity to perfect themselves in their own sphere of action. Nothing should be permitted to interfere with their training or the discharge of their proper functions. They should be supplied with officers regardless of all other demands upon the Corps of Engineers. Other duties, civil duties, duties of high importance, have been assigned to the Corps in order to make it possible to maintain a body of trained engineers for use in war. These duties afford a training which is of the greatest value, and the efficiency of the Corps would be seriously affected if we were to be separated from them; for that would amount to taking us away from work and sending us back to school to keep us busy. It is manifest that in

time of peace the military engineer can not find real employment for his profession, and it is equally clear that practice as a civil engineer is excellent training for the doing of any kind of engineering work.

On the other hand, if the School is of real importance, and the writer is convinced that it is, within its proper limits, then it should receive its just consideration and dues.

The problem in a nutshell is this: Given a certain number of officers in a corps of engineers, is it possible by separating some of them from the proper work of the corps, and placing them in a school, to improve the efficiency of the corps as a whole, so that the amount of work accomplished is increased or its quality bettered?

The writer believes that it *is* practicable and advantageous to do this. If this belief is correct, then there must be some definite relation between the corps and the school, which should fix the proportion of the corps to be employed at the school to give the maximum efficiency. If no officers go to the school, all will be available for work. If one man can be employed at the school in collecting, compiling, and publishing professional information, so that through such information the corps is enabled to accomplish more than it could do without the information, but with that officer in his normal place, then the school is useful. If two men at the school can secure a still greater efficiency of the corps, then the school should be increased to two; and so on. After the proper number of officers to collect and dispense knowledge has been determined, a further problem arises. Can the efficiency of the corps be further increased by sending a number of officers as students to the school for a time? If so, how many should go, and for what time?

Greater wisdom than the writer's is needed to answer these questions; but it is safe to say that the shorter the time necessary to impart the desired education the better for the work of the corps, and this time can be shortened for a given standard of education only by means of the best equipment and other facilities and by rigidly enforcing the principle of non-interference with the school by other interests.

# Selected Articles of Engineering Interest

Compiled by Henry E. Haferkorn, Librarian, Engineer School

*Bridges.*

The bridges of New York City: their design, construction, and chief traffic relation. By T. K. Thomson. Engineering Magazine, Sept.,'09, pp. 913-928.

Difficult bridge work in Great Britain. Engineering News, July 1,'09, pp. 8-10. Illustrated.

The erection of the Blackwells Island Bridge, New York. By F. W. Cohen. Journal of Engineers Club of Central Pennsylvania, Feb., '09, pp. 57-99. Illustrated, diagrams.

The Monroe Street Bridge, Spokane, Wash.; a concrete bridge containing a 282-foot arch. By J. C. Ralston. Engineering News, Sept. 2,'09, p. 242. Diagrams.

*Caissons.*

Concrete-steel caissons: their development and use for breakwaters, piers, and revetments. By W. V. Judson, Major, Corps of Engineers, U. S. A. Journal, Western Society of Engineers, Aug., '09, pp. 533-608. Illustrated, diagrams and tables.

*Cofferdams.*

The Black Rock Lock Cofferdam at Buffalo, N. Y. Engineering Record, Apr. 3,'09, pp. 385, 386. Illustrated.

*Concrete, plain and reinforced.*

Electrolysis of reinforced concrete. By A. S. Langsdorf. Journal of Association of Engineering Societies, Feb.,'09, pp. 69-73. Illustrated. Discussion in June, pp. 365, 366.

Tests of plain and reinforced concrete columns. By M. O. Withey. Engineering Record, July 10,'09, pp. 41-46. Illustrated, diagrams.

*Filtration.*

Alternative designs for hand-washed and machine-washed slow-sandwater filters, Borough of Queens, New York City. By I. M. de Varona. Engineering News, May 20,'09, pp. 556, 557. Illustrated.

Recent upward water filters. Engineering Record, May 15,'09, p. 637.

Notes on certain points in the design of large filtration plants. By S. B. Russell. Journal of Association of Engineering Societies, June,'09, pp. 323-336. Diagrams, tables.

*Fireproof Construction.*

Modern fireproof construction, facts and figures. By W. N. Moorhouse. Bulletin No. 5, Canadian Society of Civil Engineers, May,'09, pp. 8-27. Diagrams and plates.

*Floods.*

Flood protection in the Kansas River Valley at Kansas City. By J. Y. Olesen, United States Engineer Office, Kansas City. Engineering News, July 15,'09, pp. 82-84. Diagrams and tables.

*Heating and Ventilation.*

Design of a central heating system with forced circulation of hot water. By Jos. T. Maguire. Engineering News, Sept. 2, pp. 247, 248. Diagrams.

*Hydraulic Tables.*

Hydraulic tables. By Jos. H. Harper. Journal of Association of Engineering Societies, Feb.,'09, pp. 74-78.

*Hydroelectric Power Plants.*

Cedar River power development of the city of Seattle, Wash. By L. P. Zimmermann. Engineering News, June 17,'09, pp. 647-650. Illustrated.

*Locks and Lock Gates.*

Reply to the criticism of the Burley type of lock. By Geo. A. Burley. Engineering News, Sept. 2,'09, p. 255.

*Dams.*

A simple plant for building a dam and reservoir. Engineering Record, July 10, '09, p. 39. Illustrated, diagrams.

The slide in the Necaxa hydraulic-fill dam. By James D. Schuyler. Engineering News, July 15,'09, pp. 72-74. Illustrated. Editorial, pp. 77, 78. The same, Engineering News, July 22,'09, p. 99.

*Earthquakes.*

Earthquakes in the light of the new seismology. By Prof. O. C. S. Carter. Journal, Franklin Inst., June,'09, pp. 434-473. Illustrated.

Engineering and building construction in earthquake countries. The action of shocks and types of quake-proof structures. By W. H. Hobbs, Engineering Magazine, Sept.,'09, pp. 929-947. Illustrated.

*Engineers.*

George Adgate, M.W.S.E., 1845-1909. Memorial. Journal Western Society of Engineers, Aug.,'09, pp. 609-612. With portrait.

Quinette de Rochemont, 1838-1908. Notice sur la vie et les travaux du Baron Quinette de Rochemont, inspecteur general des Ponts et Chaussees, par G. De Joly. Annals des Ponts et Chaussees. Partie technique, tome 39, Mai-Juin, '09, 7-23.

Thomas Taylor Johnston, 1856-1909. Memorial. Journal Western Society of Engineers, Aug.,'09, p. 616. With portrait. (Was employed under Col. Casey, Maj. C. R. Suter, Corps of Engineers, etc.)

The status of the civil engineer's profession in the United States. By Onward Bates. Engineering Record, July 10,'09, pp. 34-36; the same, Engineering News, July 15,'09, pp. 74, 75. Status of the civil engineer in Great Britain. By Chas. C. Inglis, ibid., pp. 75, 76.

Annual convention of the American Society of Civil Engineers. Engineering Record Supplement, July 17,'09, pp. 43, 44; same, Engineering News, July 15,'09, p. 81.

*Materials of Construction.*

Good concrete and how to get it. By Frank M. Ikey, Municipal Engineering, May,'09, pp. 293-296.

Protective coatings for structural materials. By R. S. Perry. Journal Western Society Engineers, June,'09, pp. 399-417.

*Mathematics.*

A museum to illustrate the development of mathematics. By H. T. Wade. Scientific American, July 3,'09, p. 10. Illustrated.

*Panama Canal.*

The construction plant for the Gatun locks of the Panama Canal. Engineering Record, July 17,'09, pp. 60-65. Diagrams.

The designs for emergency movable dams for the Panama Canal. By T. B. Monniche, under direction of Col. H. F. Hodges, Corps of Engineers. Engineering News, July 22,'09, pp. 96-98. Diagrams.

The Gatun experiments on seepage through earth dams and their interpretation. Letter to the Editor by C. E. Gregory. Engineering News, July 22,'09, pp. 104,105.

The locks of the Panama Canal. Engineering News, July 15,'09, pp. 61-65. Illustrated, diagrams.

Three years in the Canal Zone. Journal of Association of Engineering Societies, June,'09, pp. 344-362.

*Phototopography.*

Phototopography, with special reference to the Alaskan boundary. By P. W. Greene. Bulletin No. 5, Canadian Society of Civil Engineers, May,'09, pp. 27-39. Illustrated, diagrams.

*Preservation of Timber.*

Difficulties in the practical work of creosoting timber. By Capt. John C. Oakes, Corps of Engineers. Engineering News, Sept. 2,'09, pp. 259-262.

*Railroad Tunnels.*

The East Side Tunnel and its approaches, Providence, R. I. By Edn. P. Dawley, Journal of Association of Engineering Societies, May,'09, pp. 293-321. Illustrated, diagrams.

*River Engineering.*

Missouri River and its bridges, by J. Y. Olesen. Engineering News, April 29, '09, pp. 460, 461. Illustrated.

A new bank revetment. By Nath. Ellery. Engineering Record, July 17,'09, p. 68. Illustrated.

Recent revetment construction on the lower Mississippi River. By Capt. Clarke S. Smith, Corps of Engineers. Engineering News, Aug. 26,'09.

*Roads.*

Asphalt macadam roadways. By C. Richardson. Engineering Record, July 17, '09, p. 77.

Materials for tarring macadam roads. Municipal Engineering, July,'09, pp. 18,19.

Methods of examination of bituminous materials for use on roads and streets. By C. Richardson and C. N. Forrest. Municipal Engineering, July,'09, pp. 20-23.

Sampittic surfacing. Discussion of Walter Wm. Crosby's paper. Proceedings American Society of Civil Engineers, May,'09. 6,000 words. Illustrated.

Tar for macadam roads from small gas works. By J. D. Taylor, Jr. Municipal Engineering, June,'09, pp. 370-372.

Tar for roads. By C. P. Price. American Gas Light Journal, May 24, '09. 4,000 words. Illustrated.

Use of tar, oils, and emulsions on macadam and earth roads. By A. R. Hirst. Engineering-Contracting, Apr. 14,'09, pp. 297-299.

*Sea Walls.*

Sea walls and breakwaters. Engineering Record, July 17,'09, pp. 81, 82.

*Strength of Materials.*

Annual meeting of the American Society of Testing Materials. Engineering Record, July 10,'09, p. 29, and July 10, '09, Supplement, pp. 35-39; illustrated. Same, Engineering News, July 8, '09, pp. 55-59, and July 15,'09, pp. 65-67.

Behavior of timber under long-continued dead loads. Illustrated. Engineering News, Aug. 26,'09, pp. 216, 217. Illustrated.

*Surveying Instruments.*

The Harrison percenter level; a surveying instrument for fixing or determining grades. By D. C. Harrison of Washington, D. C. Engineering News, Sept. 2, '09, p. 250. Illustrated.

# Editorial Notes

"What's in a name? that which we call a rose
"By any other name would smell as sweet."

This may be quite true; and yet if you happen to want a rose, you will hardly get it by asking the florist for a violet. The moral is clear; it is a good plan to call things by their own names.

Therefore a mild protest is herein entered against the widespread error of calling the Corps of Engineers the "Engineer Corps," an error which is repeatedly made by those who should know better.

The engineer corps, established and named by law in our army, is the Corps of Engineers. It is, of course, perfectly patent that this body is intended to be designated when the expression "Engineer Corps" is used; but incorrect nomenclature is never to be recommended. By capitalizing these words, the impression is given that they are the name of something; whereas there is no branch of our military service so named.

Moreover, there is the same distinction between a corps of engineers and an engineer corps that exists between a bag of money and a money bag, a bottle of beer and a beer bottle, or a garden of roses and a rose garden. It is by being a corps of engineers that the engineer corps deserves to have a name written with capitals, and then it becomes *the* Corps of Engineers.

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Speaking of names and using quotations reminds us that there is a restriction laid upon "people who live in glass houses." The name of this magazine is, in a way, a misnomer; and it has the great defect of failing to convey to the world at large a knowledge of what the magazine really is. It is believed to be a positive detriment to the development of the magazine. This matter was touched upon in the last number, and several very good suggestions have since been received. It is hoped that the new year may begin under a name which will be so clear that no explanations will be needed.

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The present number is the last for the year 1909, and it is possible to see just where we stand. The success of the PROFESSIONAL MEMOIRS has been so complete that the price of subscriptions beginning with the January number in 1910, and of renewals of subscriptions now in force,

has been reduced to $4.00. By securing new subscribers and advertisers, our friends can give the greatest assistance. Further growth of the magazine will enable the price to be reduced to a still lower figure, and possibly the number of issues each year can in time be increased to six.

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The following statement furnished the PROFESSIONAL MEMOIRS by Lieut. Col. Hodges, Acting Chairman and Chief Engineer of the Isthmian Canal Commission, is interesting in connection with the paper by the same officer on the Panama Canal, printed on page 355 of this number.

"Seismic disturbances were recorded on the instruments at Ancon Observatory on August 28 and 30, 1909. On the 28th, four distinct shocks were recorded, all of minor intensity, the first occurring about 11 a. m. and the last at a little past 5 p. m., none of these being accompanied by any preliminary tremors. On the morning of the 30th, about 8 o'clock, a shock of more pronounced intensity occurred, the tremors continuing for about twenty minutes. The vibrations were sufficient to throw the pens from the cylinders of the high-tension instruments. This disturbance was felt by many people at various points in the Zone. At Gatun, the clock in the fluviograph station, the pendulum of which is about 30 inches long, was stopped, presumably by the earth movement.

"The shock did not interfere in any way with the construction work of the Canal. Investigation fails to show that damage was done to any of the buildings in the Canal Zone or in the cities of Panama and Colon, nor have any leaks developed in any of the water-supply dams or reservoirs. While it was more intense than any other recently experienced, the shock was not severe."

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# INDEX *and* ERRATA

Professional Memoirs
CORPS OF ENGINEERS, UNITED STATES ARMY
*AND*
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WASHINGTON BARRACKS, D. C.

VOLUMES I-V, *Inclusive*
[1909–1913]

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*VOLUMES I–V*

*(1909-1913)*

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## Errata, Professional Memoirs

*Volumes I to V*

Volume I, page 319—

Ninth line from bottom: for the figures 0.96 and 0.98 read their reciprocals. 1.04 and 1.02.

Volume II, page 98—

A letter from Capt. J. A. Woodruff, Corps of Engineers, received after his article, A Combined Position Sketch (see page 50), had been printed, requests that the following corrections be made: Page 53, 7th line, for east read west; 8th line, for west read east in both cases; 16th line, for eastern read western; 17th line, for west read east; page 54, 1st line, for western read eastern; 2nd line, for east read west.

Volume II, page 262—

Last line: page 167, read Janvier; not Janiver. Thirteenth line from bottom page 173, read 2 of 4, not 2 to 4.

Volume IV, page 324—

In the last part of the second term of the equation on page 591, the denominator should read $1 +$ and the parenthesis around the numerator should be omitted.

Page 596, line 15, the word "footing" should read "footings," and in line 17, the words "center of" should be stricken out.

Volume IV, page 668—

In connection with the article by Lieut. James G. Steese on "The Corps of Engineers and the Isthmian Canal," which appeared in the July-August number of the PROFESSIONAL MEMOIRS, the following correction should be made:

Col. Wm. M. Black (then Major) and Lieut. Mark Brooke, Corps of Engineers, were placed under the orders of the Isthmian Canal Commission on April 1, 1903, instead of March, 1904. They proceeded to Panama and were stationed at Culebra. The duty assigned to Colonel Black was to observe and report on the work of the new Panama Canal Company, reporting particularly on the expenditures made month by month and the work accomplished. Colonel Black was absent from the Isthmus May 4, 1904, when the actual transfer was made, but returned thereto a few days after and remained as Acting Chief Engineer of the Commission until the arrival of Mr. John F. Wallace, who took charge of the work, July 1, 1904.

Volume V, page 248—

The following table of costs is furnished by Maj. E. H. Schulz to replace table of cost shown on pages 710 and 713, PROFESSIONAL MEMOIRS, No. 18.

*a. Willow Mattress.*

| | |
|---|---|
| 757 cords brush, at $0.892 | $675.87 |
| 776 cubic yards ballast, at $0.746 | 579.09 |
| 555 cubic yards spalls, at $0.702 | 389.70 |
| Wire strand, clips | 204.43 |
| Towboat service | 784.00 |
| Labor, superintendence and miscellaneous | 2,669.59 |
| | $5,302.68 |

*b. Concrete Paving.*

| | |
|---|---|
| 1,156 cubic yards gravel, at $1.533 plus | $1,772.35 |
| Grading bank, 1,000 linear feet, at $0.946007 | 946.07 |
| Reinforcement | 749.32 |
| 821¾ barrels Portland cement at $1.15 | 945.01 |
| Labor, superintendence, and miscellaneous | 1,881.33 |
| | $6,294.08 |

*c. Flexible Concrete Blocks.*

| | |
|---|---|
| 120 cubic yards gravel, at $1.533 | $183.96 |
| Reinforcement | 221.65 |
| 182 barrels Portland cement, at $1.15 | 209.30 |
| Labor, etc., making blocks | 636.00 |
| Labor, etc., placing blocks | 685.12 |
| | $1,936.03 |

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